RADIOLOGICAL SITE AND BACKGROUND INVESTIGATIONS

SAMPLING AND ANALYSIS PLAN

Revision 2
FINAL

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TABLE OF CONTENTS

1.0 **INTRODUCTION** **1-1**
1.1 Background 1-1
1.2 Project Activities and Objectives 1-5
1.2.1 Background Area(s) – Activities/Objectives 1-6
1.2.2 On-Site – Activities/Objectives 1-7
1.3 Document Organization 1-8
2.0 **DATA QUALITY OBJECTIVES** **2-1**
2.1 Definition of Data Quality Objectives 2-1
2.2 Supporting Information for Problem Definition 2-2
2.2.1 Site History and Background 2-2
2.2.2 Conceptual Model 2-3
2.2.3 Background Locations and Selection 2-8
2.2.4 Facility Maps 2-10
3.0 **SAMPLING DESIGN – BACKGROUND AND ON-SITE AREAS** **3-1**
3.1 Background Area Sampling Approach 3-2
3.2 On-Site Sampling Approach 3-6
3.3 Summary of Sampling Methods and Rationale 3-7
3.3.1 Reconnaissance Field Survey 3-8
3.3.2 GPS-Based Gamma Survey 3-8
3.3.3 Radon Flux Measurements 3-9
3.3.4 Correlation Studies 3-9
3.3.5 COPC Soil Sampling in Background Areas 3-10
4.0 **DATA REPORTING** **4-1**
5.0 **REFERENCES** **5-1**

LIST OF TABLES

(Attached at end of text)

Table 2-1	Radiological and Background Area Data Quality Objectives
Table 3-1	Sample Collection Summary

LIST OF FIGURES

Figure 2-1	Typical Permian Section
Figure 2-2	P4 Typical Mine Cross Section
Figure 2-3	Caldwell Canyon Geologic Map and Background Locations
Figure 2-4	Caldwell Canyon Aerial Photo and Background Locations Overview
Figure 2-5	Caldwell Canyon Aerial Photo and Background Locations
Figure 2-6	Background Area Plan View and Sampling Approach
Figure 2-7	Blackfoot Bridge Geologic Map and Background Locations
Figure 2-8	Blackfoot Bridge Aerial Photo and Background Locations Overview
Figure 2-9	Blackfoot Bridge Aerial Photo and Background Locations
Figure 2-10	Hypothetical On-Site Sampling Approach at Enoch Valley Mine
Figure 3-1	Enoch Valley Mine
Figure 3-2	Geologic Map with Waste Rock and Pit Boundaries

APPENDICES

Appendix A	Field Sampling Plan
Appendix B	Quality Assurance Project Plan
Appendix C	Health and Safety Plan Activity Hazard Analysis
Appendix D	Document Comments and Responses

ACRONYMS AND ABBREVIATIONS

A/T	Agencies and Tribes
bgs	below ground surface
BLM	Bureau of Land Management (Department of Interior)
BRA	Baseline Risk Assessment
CO/AOC	Consent Order/Administrative Order on Consent
COPC	Contaminant of Potential Concern
CWS	center waste shale
DOI	Department of the Interior
DQOs	Data Quality Objectives
DSR	Data Summary Report
DVS	Data validation summary
e.g.	*exempli gratia* (Latin, for example)
ERA	Ecological Risk Assessment
FSP	Field Sampling Plan
ft	feet
GPS	Global positioning system
HASP	Health and Safety Plan
HHRA	Human Health Risk Assessment
HPIC	High Pressure Ion Chamber
HQ	hazard quotient
IDEQ	Idaho Department of Environmental Quality
i.e.	*id est* (Latin, that is to say; in other words)
LRA	Livestock Risk Assessment
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
mg/kg	milligrams per kilogram
mrem	millirem
MWH	MWH, Inc. (formerly Montgomery Watson Harza, Inc.)
NaI	sodium iodide
NRC	Nuclear Regulatory Commission
P4	P4 Production, L.L.C.
pCi/g	picocuries per gram
pCi/m^2s	picocuries per square meter per second

QAPP	Quality Assurance Project Plan
Ra-226	Radium-226 (radium isotope, uranium decay product)
RI/FS	Remedial Investigation/Feasibility Study
SAP	Sampling and Analysis Plan
Sites	Ballard, Henry and Enoch Valley Mines
SOP	Standard Operating Procedure
Th-232	Thorium-232
Tribes	Shoshone-Bannock Tribes
U-234	Uranium-234 (uranium isotope)
U-235	Uranium 235-(uranium isotope)
U-238	Uranium 238-(uranium isotope)
UCL	upper confidence limit
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USL	upper simultaneous limit
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

1.0 INTRODUCTION

The background investigation described in this Sampling and Analysis Plan (SAP) is being performed as part of the characterization of the three historic P4 Production (P4) phosphate mines (i.e., the Ballard, Henry, and Enoch Valley Mines collectively known as "the Sites") in southeastern Idaho. This document has been prepared by MWH Americas, Inc. (MWH) on behalf of P4, to supplement the CERCLA activities described in the Administrative Settlement Agreement and Order on Consent/ Consent Order for Remedial Investigation/Feasibility Study (2009 CO/AOC; USEPA, 2009). The 2009 CO/AOC is a voluntary agreement between P4 and the United States Environmental Protection Agency (USEPA), the Idaho Department of Environmental Quality (IDEQ), the United States Department of Agriculture, United States Forest Service (USFS), the United States Department of the Interior (DOI), United States Bureau of Land Management (BLM), and the Shoshone-Bannock Tribes (Tribes), collectively referred to as the "Agencies and Tribes" or A/Ts.

1.1 Background

In 2011, a *Remedial Investigation/Feasibility Study Work Plan for P4's Ballard, Henry, and Enoch Valley Mines* (*RI/FS Work Plan*; MWH, 2011) was finalized and approved by the A/Ts for the comprehensive mine-specific RI/FS that is being conducted at the Sites. The draft *Ballard Mine RI Report* (MWH, 2013a) was completed in November 2013 and includes characterization of the nature and extent of constituents of potential concern (COPCs) in six media: soils, vegetation, sediment, groundwater, surface water, and biota. As noted in the *Ballard Mine RI Report*, the primary source of COPCs at the Sites is the waste rock derived from the Phosphoria Formation that has been placed in the various dumps and mine pits throughout the Sites. Researchers have noted that concentrations of cadmium, chromium, selenium, silver, uranium, and zinc are "exceptionally" enriched in the Meade Peak Member of the Phosphoria Formation compared to their respective averages in world-wide shale (Herring and Gauch, 2004).

At the Sites, the middle or center waste shale (CWS), found between ore horizons of the Meade Peak Member, is the primary rock type in the waste rock dumps and contributes most of the COPC loading detected in soils, surface water, and groundwater. It also is possible that in undisturbed (i.e., pre-mining) areas, the enriched concentrations of COPCs in the Meade Peak Member could result in an elevated background in soils overlying the Phosphoria Formation and possibly in soils downslope of formation outcrops due to mass creep.

The occurrence of an elevated concentration of an element in soil when the concentration of the element in parent bedrock is elevated is a commonly recognized geochemical principle, where the soil that forms on a specific lithology will retain some of the geochemical characteristics of the parent rock including elemental enrichments and depletions (Levinson, 1980). This principle is a basis for the use of soil sampling in mineral exploration, and has been used successfully for locating elemental enrichment (ore deposits) in the underlying bedrock (see Levinson, 1980, for examples). However, it also needs to be stated that the degree to which concentrations of individual elements in a soil reflect elemental composition of the underlying bedrock will vary by element because of the unique geochemical behavior of the individual elements in the geologic unit and the climactic conditions present during the soil forming process. For example, the solubility of an individual element under the specific soil pH and Eh will have a direct effect on whether the element is possibly enriched (e.g., nickel and chromium in lateritic soils), or depleted relative to the bedrock. This has been observed in weathered Meade Peak where mercury, nickel, and selenium are readily depleted in soils overlying the formation, but silver, barium, uranium, vanadium, and zirconium are slightly enriched (Herring and Grauch, 2004). Other elements including chromium, copper, molybdenum, antimony, and zinc may also be slightly depleted in the soils relative to the Meade Peak. However, it should also be noted that while the concentration of an element may be lower in the soil relative to the Meade Peak Member, the absolute concentration still may be elevated relative to other soils in the area, and with respect to regulatory and risk-based criteria.

Due to the physical and chemical characteristics of the Phosphoria Formation bedrock, it often weathers relatively quickly into soils and forms "swales" in the natural setting rather than bedrock outcrops. At the Sites, these same physical and chemical processes quickly convert the waste rock containing Phosphoria members into soils, and precipitation infiltrating these areas releases the COPCs contained in the rock into the surface water and groundwater systems. In addition, plants can directly uptake the COPCs from the Phosphoria-derived soils and Phosphoria-influenced waters.

Uranium is known to be elevated in the phosphate ores mined at the Sites, as referenced above, and previously has been identified as a COPC in soils. Soil samples from the Sites have specifically been collected and analyzed for total uranium (i.e., uranium not speciated into individual isotopes). Data also have been collected for total uranium in surface water, groundwater, stream sediment, and vegetation. The evaluation of human health risk from uranium series radionuclides in the soil and indoor air at the Sites needs to address both chemical and radiological risks.

A Baseline Risk Assessment (BRA) was performed as part of the *Ballard Mine RI Report* to evaluate the chemical and radiological risks associated with the COPCs detected in the various media on human health and the environment. Results of the Ballard Mine Human Health Risk Assessment (HHRA) in the BRA show that the chemical and/or radiological risks associated with COPCs that are naturally elevated in the Meade Peak Member, compared to the adjacent geologic units, exceed acceptable risk or hazard criteria. For example, chemical risk estimates for arsenic exceed the State of Idaho's acceptable cancer risk criterion of 1×10^{-5} for a hypothetical future resident and a current/future Native American exposed to arsenic in upland soil. In addition, the chemical noncancer hazard estimates for a current/future Native American exposed to arsenic, selenium, total uranium, and several other COPCs in culturally significant plants grown in upland soil, and for a hypothetical future resident exposed to arsenic, selenium, thallium, and several other COPCs in fruits and vegetables grown in upland soils, exceed the State of Idaho and USEPA acceptable hazard quotient (HQ) of 1.

P4 evaluated radiological risks associated with uranium in the BRA based on total uranium concentrations measured in Site soils and very conservative, default assumptions developed by the USEPA to model concentrations of radium-226 (Ra-226) in soil and of Radon-222 (radon) in air. This approach yielded total human health cancer risk estimates in excess of 1 x 10^{-5} for direct exposure to uranium in upland soil, and 1 x 10^{-2} for inhalation of radon, at the Ballard Mine. The majority of the radiological risk is clearly driven by radon inhalation. The combined radiological risk estimate equates to 99% of the total (chemical and radiological) cancer risk estimate for the hypothetical future resident, and was attributable to total uranium concentrations in soils collected from the Ballard Site waste rock and mine pits.

Because of the conservative assumptions that are needed to address uncertainties in modeling radiogenic exposures and risks from total uranium concentrations in soil, P4 believes that the above human health risk estimates for the Ballard Site represent a gross overestimation of Site cancer risks. This overestimation of radiogenic human health risks in the Ballard Mine HHRA (MWH, 2013a) is likely due to (1) the conservative assumptions used in sequential decay modeling of radium-226 and radon-222 activities from total uranium concentrations, and (2) the fact that concentrations of radionuclides in background, as determined from soil samples collected near the Sites during the RI, are not representative of the complete geologic sequence in this historic mining district and biased low. This issue also applies to other elevated COPCs detected at the Site including metals such as arsenic.

The background samples collected during the RI represent only a portion of the potential area disturbed by the historic mining operations, and did not include soils derived from, and overlying, the Phosphoria Formation. The Phosphoria Formation exposure represents up to approximately 50 percent of the land area disturbed by a typical phosphate mining operation. The ore bearing Meade Peak Member of the Phosphoria Formation represents a smaller portion of this (i.e., approximately 20 percent) depending on the configuration of the mine pit and waste dumps. As a result, truly representative background data, which are important to any evaluation of Site features, their impacts, and their risks, are not currently available for any of the COPCs. However, the collection of radiogenic information and background soil samples over the Phosphoria Formation (i.e., including Meade Peak, Rex Chert and Cherty Shale Members) proposed in this Radiological Site and Background Investigations SAP, in conjunction with new and existing 2009 data from the Dinwoody and Wells Formations soils data, should serve as the "representative" or "true" baseline or background for radiologic constituents and COPCs in Site soils prior to mining.

1.2 Project Activities and Objectives

As discussed above, uncertainties related to the assessment of background and Site risks associated with uranium and other COPCs are significant, and to evaluate risks properly, additional data are required as described in this SAP. For example, GPS-based gamma surveys, radon flux measurements, and exposure rate measurements are proposed for collection at selected background locations and from the Sites to accurately estimate potential future radiological exposures and risks related to external radiation and inhalation of radon in indoor air.

In accordance with the SAP, P4 will collect: (1) representative radiological measurements, both On-Site and in appropriate background locations (where representative radiological measurements and soil samples have not previously been collected), and (2) supplemental background data for chemical COPCs in soil primarily over the Phosphoria Formation. These supplemental data will be used to put human health risk estimates calculated for the Ballard Mine in appropriate context during preparation of the Ballard Mine FS, and to calculate more representative human health risk estimates for radiogenic and metal/metalloid COPCs during preparation of the BRAs for the Enoch Valley and Henry Mines. Such evaluations will then account for the naturally elevated background concentrations of uranium and other COPCs present in the Phosphate Resource Area but not currently represented in the current background data used in the Ballard BRA.

The overall objectives of this SAP are to: (1) present the Data Quality Objectives (DQOs) necessary to define the sampling objectives, (2) identify the sampling equipment, procedures, and locations necessary to support the study objectives (primarily in the Field Sampling Plan [FSP] in Appendix A), and (3) discuss the reporting requirement associated with the data collection effort related to these issues. The overall goal of the data collection effort presented herein is to reduce uncertainties in the BRAs for the Sites. The following sampling activities, each with a specific objective, will be conducted in the selected Background Areas and at the Sites (On-Site):

1.2.1 Background Area(s) – Activities/Objectives

1) Collect data from reference background areas located at the Blackfoot Bridge and Caldwell Canyon sites. Each background area contains a primary and alternate location as presented in Section 2.2.2.
2) Collection of gamma measurements, through GPS-based gamma surveys, within a selected background reference area that through correlation studies (Objective 4 below) can be used to predict total uranium (mg/kg) and Ra-226 (pCi/g) concentrations in soil and exposure rates for use in radiological risk evaluations. Ra-226 concentrations in the background reference area will be used to calculate background risks posed by Ra-226 exposures to a hypothetical future resident. Exposure rate measurements, made using a high pressure ionization chamber (HPIC) will be qualitatively compared to their respective USEPA dose guidelines.
3) Collection of radon flux measurements (i.e., radon release rates from soil surface measured as an activity per unit area and time). The flux measurements will be the basis to predict background radon air concentrations and for the calculation of background risks associated with radon inhalation exposures in a hypothetical future resident.
4) Collection of random composite soil samples for analysis of soil COPCs for background level calculations and risk evaluations. Supplemental soil COPC data will be used to supplement/revise the background levels for upland soils presented in the *Background Levels Development Technical Memorandum* (MWH, 2013b).
5) Collection of random composite soil samples for total uranium and Ra-226 via chemical and gamma spectroscopy analyses as well as real-time radiological measurements (GPS-based gamma surveys, static gamma counts, and exposure

rates): (a) for correlation purposes, (b) to confirm secular equilibrium, (c) to improve the robustness of the existing data sets, and (d) for use in the risk assessments. The gamma spectroscopy analysis also will yield potassium-40 (K-40) and thorium-232 (Th-232) concentrations in soil, which may be useful in evaluating anomalies in the spatial or frequency distribution of gamma count rates; and trends in the correlations between radionuclide concentrations and gamma emissions and therefore exposure rates, which may be useful in evaluating gamma anomalies.

1.2.2 On-Site – Activities/Objectives

1) Collection of gamma measurements, through GPS-based gamma surveys, focused on the source areas (waste rock dumps) within the P4 Sites that: (a) can be used to select sample locations to estimate the maximum and range of uranium (thus Ra-226) concentrations and (b) through correlation studies can be converted to predicted total uranium and Ra-226 concentrations and exposure rate measurements for radiological risk evaluations. Ra-226 concentrations at the Sites will be used to calculate On-Site risks posed by Ra-226 exposures to a hypothetical future resident. As above, exposure rate measurements will be qualitatively compared to their respective USEPA dose guidelines.
2) Collection of radon flux measurements (i.e., radon emanation rates measured as an activity per unit area and time). The flux measurements will be used as the basis to predict On-Site radon air concentrations and for the calculation of On-Site risks associated with radon inhalation exposures in a hypothetical future resident.
3) Collection of random composite soil samples for total uranium and Ra-226 via chemical and gamma spectroscopy analyses as well as real-time radiological measurements (GPS-based gamma surveys, static gamma counts, and exposure rates): (a) for correlation purposes, (b) to confirm secular equilibrium, (c) to improve the robustness of the existing data sets, and (d) for use in the risk assessments. The gamma spectroscopy analysis also will yield K-40 and Th-232 concentrations in soil, which may be useful in evaluating anomalies in the spatial

or frequency distribution of gamma count rates; and trends in the correlations between radionuclide concentrations and gamma emissions and therefore exposure rates, which may be useful in evaluating gamma anomalies.

The above radiological measurements in the Background and On-Site Areas will allow P4 to calculate radiological risks directly instead of relying on conversion factors in empirical formulae. In addition, collection of COPC concentrations in background soil will allow for the statistical derivation of more representative background concentrations to be used in the calculation of background and incremental risk estimates, and potentially for the development of future cleanup levels.

1.3 Document Organization

While the SAP components are often prepared as stand-alone documents, it should be recognized that the background characterization described herein is part of the overall characterization of the Sites within the RI/FS. Therefore, elements of the more extensive *RI/FS Work Plan* (e.g., site background and data gaps analyses) and *Ballard RI Report* are not repeated in this SAP.

The introduction including the background and project objectives are contained in Sections 1.1 and 1.2, above. A key component of the project planning process includes an evaluation of the DQOs for the radiological and background investigations. The DQO analysis for the radiological and background investigations is presented in Section 2.0. Section 3.0 details the sample design in the background areas and On-Site. Section 4.0 summarizes the reporting requirements for the radiological and background investigations.

The other primary components of this SAP are:

- Appendix A - Field Sampling Plan (FSP),
- Appendix B - Quality Assurance Project Plan (QAPP), and
- Appendix C - Health and Safety Plan (HASP).

- Appendix D - Document Comments and Responses (currently unused)

The primary QAPP (and QAPP Addendum) and HASP for the overall RI/FS program are provided by reference and found in Appendices D6 and E of the *RI/FS Work Plan*.

2.0 DATA QUALITY OBJECTIVES

2.1 Definition of Data Quality Objectives

The DQOs discussed in this section were used to guide the development of the FSP and QAPP in Appendices A and B of this SAP. The DQOs identify the quantity and quality of data to be collected during the proposed investigation and support the decision-making process related to the RI/FS program. The DQOs described herein are consistent with USEPA DQO guidance (USEPA, 2006) and use the prescribed seven-step process:

1) State the problem
2) Identify the goals of the study
3) Identify information inputs
4) Define the boundaries of the study
5) Develop the analytic approach
6) Specify performance or acceptance criteria
7) Develop the plan for obtaining data

Within the DQOs, the principal study questions (from Step 2) have corresponding statements, as appropriate, in each of the remaining DQO steps. Outputs are given in each step and follow the 2006 DQO guidance (USEPA, 2006). Refer to Section 1.2 for a general discussion of the sampling program objectives.

Each step of the DQO process defines criteria that will be used to establish the final data collection design. The first five steps are primarily focused on identifying qualitative criteria, such as:

- The nature of the problem that has initiated the study and a conceptual model of the environmental hazard to be investigated.

- The decisions or estimates that need to be made and the order of priority for resolving them.

- The type of data needed.
- An analytic approach or decision rule that defines the logic for how the data will be used to draw conclusions from the study findings (USEPA, 2006).

Step 6 in the DQO process establishes acceptable quantitative criteria on the quality and quantity of the data to be collected, relative to its ultimate use. For these investigations, the data will be collected primarily to determine radiological activities and concentrations of COPCs including uranium in background and On-Site soils for subsequent use in risk analysis.

Step 7 of the DQO process develops a collection design to generate data meeting the quantitative and qualitative criteria specified at the end of Step 6. The output from this step is largely contained in the FSP and QAPP (in Appendices A and B). Table 2-1 presents detailed information related to each of the seven DQO steps for the radiological and background investigations. Additional supporting information necessary to make informed decisions is provided in Section 2.2 below.

2.2 Supporting Information for Problem Definition

Key factors that need to be considered in the DQO development process are the Site history and background information, and conceptual model to help formulate the problem statements (DQO Step 1). Further information supporting the sample types, size and distribution also is presented in Section 3.0.

2.2.1 Site History and Background

Extensive information on the history and background of the Sites is provided in the *RI/FS Work Plan* (MWH, 2011) and the *Ballard Mine RI Report* (MWH, 2013a).

2.2.2 Conceptual Model

Lithogeochemical Conceptual Model. Uranium previously has been identified as a COPC for the Sites. Soil samples, as well as other media from the Sites, have specifically been collected and analyzed for total uranium but not individual uranium species or decay products, such as Ra-226 and radon. The general conceptual model for the dispersion of the uranium series radionuclides at the Sites has to account for the source and mining process. Uranium concentrations are naturally elevated in the Phosphate Resource Area, and are specifically elevated in portions of the Permian-age Phosphoria Formation. Elevated uranium concentrations, as determined through down-hole gamma radiation surveys, have routinely been used during exploration to locate phosphate ore in the Meade Peak Member of the Phosphoria Formation (P4 Production, personal communication). This elevated uranium also has been well documented by the U.S. Geological Survey and other researchers (e.g., Hale, 1967, Dunlap Derkey, et. al., 1980, Herring, et al., 2001; Herring and Grauch, 2004; and Zielinski, et al., 2004).

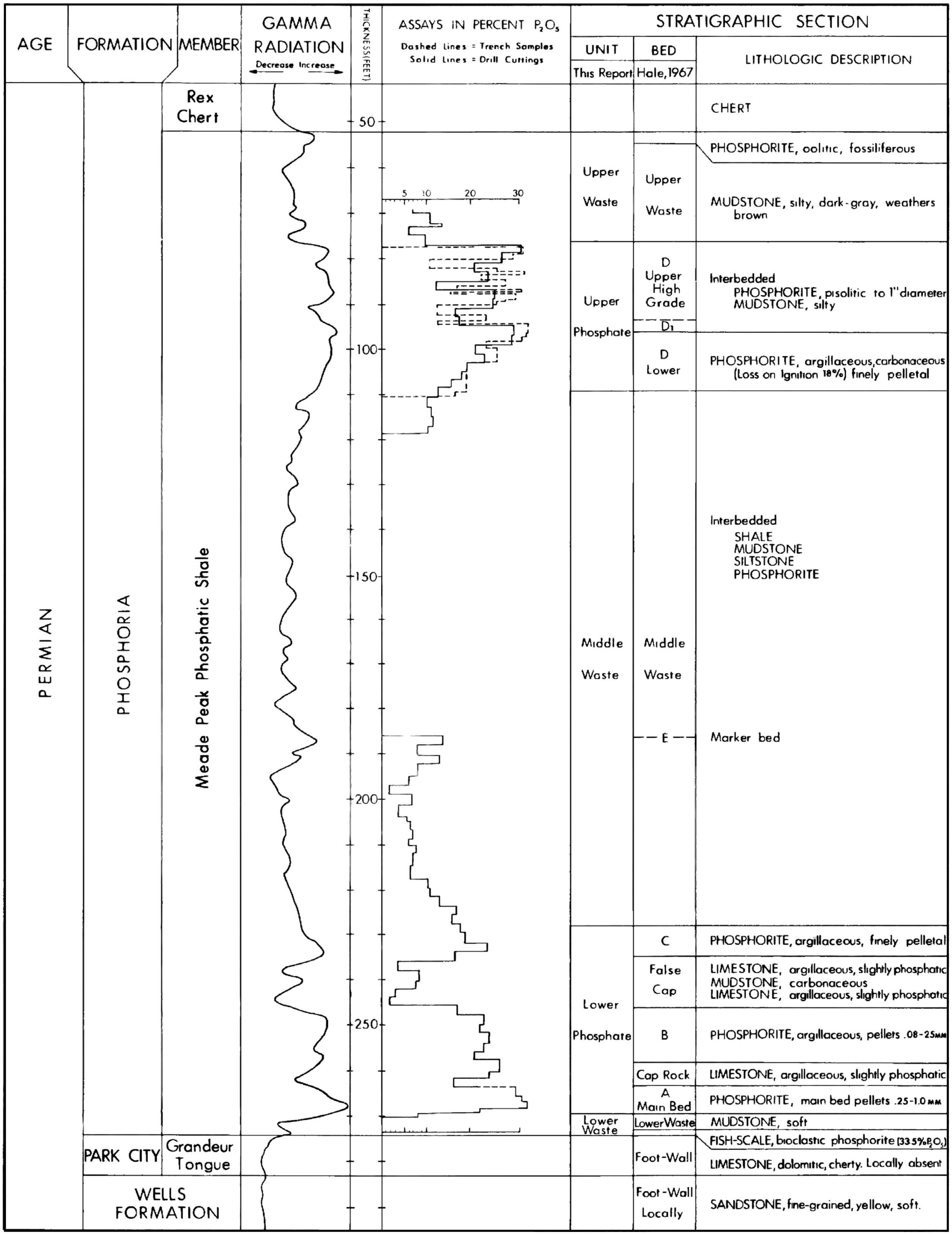
The Phosphoria Formation is subdivided into four members in this region of Southeastern Idaho. The four members from top to bottom are:

- The Retort Phosphatic Shale (discontinuous locally)
- The Cherty Shale
- The Rex Chert
- The Meade Peak Phosphatic Shale (where the ore units are found)

Specific beds from the Meade Peak Member are mined for phosphate ore. Figure 2-1, below, from Upper Valley Quadrangle, Caribou County, Idaho map report (USGS, 1980) depicts a stratigraphic section through the Meade Peak member of the Phosphoria Formation and shows the gamma radiation response found in boreholes drilled in the area. It is important to note that only two of the ore units are processed: the upper phosphate ore bed and the lower phosphate ore bed (both of which have high gamma radiation responses). The other units (upper, middle and lower waste shale beds, which are associated with much lower gamma radiation responses), are typically the mining waste along with portions of the over and underlying formations (i.e., the Phosphoria Formation Rex Chert and Cherty Shale Members, Dinwoody Formation, and Wells Formation). These waste shales are organic rich with sulfides and contain some elevated concentrations of several other COPCs including selenium. However, uranium is primarily associated with the mineral apatite which is the primary ore mineral (Perkins and Foster, 2004).

The mining process extracts the phosphate ore and associated overburden (i.e., the soil and rock overlying the ore and interbeds between ore horizons). The phosphate ore enriched with the highest concentrations of COPC (i.e., mostly metals including uranium) is hauled to P4's plant near Soda Springs, Idaho for processing, and the overburden materials are either placed back in the pits as backfill or placed in external waste rock dumps. As a result, the rock (ore) with the most elevated uranium concentrations ends up in the slag material after the ore is processed at P4's processing facility in Soda Springs, Idaho, and is not returned in any significant volume to the Sites (a small volume of slag is stored at the Ballard Shop Area for use in road repair). Therefore, the mining process could result in uranium concentrations and associated radiogenic concerns (e.g., radon emissions) that are lower in the waste rock remaining at the Site than over the native, in place, ore body.

The waste rock remaining at the Sites is a mixture of lithologies including: the Wells Formation limestone and sandstone, non-ore grade shales and cherts from: (1) the Rex Chert, (2) cherty shale and interbeds within the Meade Peak Members of the Phosphoria Formation, and (3) possibly some Dinwoody Formation shale and/or mudstone. In addition, any of these units can be covered during the placement of waste rock. Figure 2-2 illustrates a typical mine configuration and shows the rock that is excavated and where the waste rock is often placed during mining. Refer to the USGS Figure 2-1 to better understand e distribution of ore to waste in a typical cross-section of the Meade Peak Member of the Phosphoria Formation.



SOURCE:
Figure 3. Typical Permian section, upper Dry Valley area, Caribou County, Idaho (from Hale, 1967) as reported in USGS, 1980.

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RADIOLOGICAL BACKGROUND SAP

TYPICAL PERMIAN SECTION

Figure 2-1

FILE *Fig 2-1_Typical Permian Section_Feb2014.ai* *19 Feb 2014*

Most of the waste rock dumps at the Sites have been reclaimed, with the exception of the Ballard Mine Site. The typical reclamation process included the placement of cover soil primarily to enhance vegetation growth, which in turn reduces water infiltration. The cover material for the waste rock often is comprised of rock, weathered rock and some native soil that was removed from over the ore and non-ore rock units during mining and stockpiled prior to excavation of the Meade Peak Member ore. Much of the cover material's uranium content is derived from the weathered Phosphoria Formation waste interbeds. It is expected that uranium and some other COPCs concentrations in cover soils on the Sites would be lower than in the Phosphoria Formation ore sequence in an undisturbed or native state. However, as a result of mining and waste rock placement, the remaining uranium mass may be dispersed over a larger total area in the waste rock piles.

Risk Assessment Conceptual Model. The risk assessment process begins with the development of a conceptual site model. The details of the risk assessment conceptual model for the P4 Site COPCs are provided in the *RI/FS Work Plan* and the *Ballard RI Report*. The primary components of the conceptual model for uranium series radionuclides in On-Site soils that support the DQOs are summarized below.

- Source – Waste rock and soils with elevated uranium content in the waste rock dumps, backfilled mine pits, and exposed mine pits.

- Release mechanisms – Natural radioactive decay of uranium series radionuclides, which includes the emission of gamma and the release of radon gas. Physical and chemical processes release uranium, uranium series radionuclides and metals/metalloids from waste rock and mine pits.

- Exposure pathways – Direct exposure to gamma radiation, inhalation of radon in indoor air, and uptake of radiological COPCs from soil into fruits and vegetables grown in affected soils.

- Receptors – Potential receptors include current/future Native Americans, hypothetical future residents, seasonal rancher, recreational fisher, recreational hunter, recreational camper/hiker, livestock, and wildlife.

The human health exposure pathways listed above are not a comprehensive listing of complete exposure pathways for human receptors; rather, they represent those exposure pathways that contributed most significantly to radiological risk associated with human exposures to uranium and uranium daughter products in the HHRA prepared for the Ballard Mine (MWH, 2013a). For other potentially complete exposure pathways and media, uranium didn't contribute significantly to human health risks in the Ballard Mine HHRA (MWH, 2013a). For example, concentrations of uranium weren't significantly elevated in surface water or groundwater, and uranium didn't contribute significantly to human health risks for these media in the Ballard Mine HHRA (MWH, 2013a). As a result, P4 is not proposing to collect radiological data for media other than soil. Finally, P4 only intends to quantitatively evaluate radiological risks for a hypothetical future resident and not the other receptors listed in the 4th bullet, above, because a hypothetical future resident represents the worst-case scenario.

In the A/T comments on the *RI/FS Work Plan*, it was stated that the assessment of chemical and radiological risks needs to include a residential exposure scenario. While it is unlikely that residential structures will be built on the existing waste rock dumps, the A/Ts believe that there is some potential for limited residential use of these areas, and such potential land use should be evaluated in the BRAs for the Sites. The hypothetical residential human health pathways that must be considered if a home or other structure were built on a reclaimed waste rock dump include: (1) direct gamma exposure to site occupants, (2) radon entry into future buildings (indoor air scenario), and to a lesser extent, (3) the intake into the body from food grown on the site and airborne radionuclides from dust.

Uranium didn't contribute significantly to potential risks for livestock or wildlife in the BRA prepared for the Ballard Mine (MWH, 2013a). As a result, the radiological data will not be used to quantitatively evaluate potential risks to livestock or wildlife in the livestock risk assessment (LRA) or in the ecological risk assessment (ERA) to be prepared for the Enoch Valley and Henry Mines.

The radiological data needed to evaluate each of the human health exposure pathways that will be evaluated for a residential exposure scenario are discussed below.

External Exposure

Uranium-238 (U-238) constitutes the majority of naturally occurring uranium and exposure to radionuclides in the U-238 decay series produces the majority of the radiological risk associated with uranium. External exposure (direct gamma exposure) at the ground surface depends primarily on the concentration of radium-226 (Ra-226; daughter product of U-238) in the shallow soils. Gamma rays from the radioactive decay of Ra-226 and its progeny have the potential to deliver a radiation dose to occupants of structures overlying soils.

Site information would suggest that Ra-226 is in secular equilibrium with U-238 at the Sites. Secular equilibrium occurs when the activity of a radioactive isotope, in this case Ra-226, is the same as its parent. In secular equilibrium, Ra-226, the progeny, decays at the same rate as the parent (U-238). The decay rates are equal because the progeny cannot decay until it is formed, and so the rate of formation of the progeny equals the rate of the very slowly decaying parent. Assuming that these ratios have not been altered by natural processes, the isotopic ratio of U-238, U-234, and U-235 at the Sites, and the U-238 and Ra-226 concentrations at the Sites may be accurately calculated. Note that the concentrations of Ra-226 in soil can be estimated from concentrations of U-238, assuming (1) secular equilibrium is present in the decay series or (2) consistent ratios of the two are observed, if secular equilibrium is not confirmed in this investigation. Thus, the composite soil samples proposed for collection in the Background and On-Site locations will be analyzed for both Ra-226 and total uranium. The gamma spectroscopy analysis also will yield K-40 and Th-232 concentrations in soil, which may be useful in evaluating anomalies in the spatial or frequency distribution of gamma count rates; and trends in the correlations between radionuclide concentrations and gamma emissions and therefore exposure rates, which may be useful in evaluating gamma anomalies.

Radon

Radon released from the soil surface, hereafter referred to as the radon flux, is expressed in units of picocuries per square meter per second (pCi/m^2s) and is expected to scale with the Ra-226 concentration for similar soil types. According to National Regulatory Commission (NRC), radon flux is largely dependent on the Ra-226 concentration in the top ten feet of soil, with the uppermost soils being more influential that deeper soils (NRC, 1984). For these Sites, the top 10 feet beneath a hypothetical future structure might be made up of natural soil or a combination of ore, waste rock, and other backfill material. Because of the more permeable nature of waste rock compared to pre-mining rock and soil, radon flux could be less inhibited in waste rock (i.e., freer gas movement).

2.2.3 Background Locations and Selection

The selection of background areas is dependent upon several criteria. The first of these criteria is the area needs to contain representative geology. The phosphate deposits mined in SE Idaho are part of the 135,100 square mile Western Phosphate Field, which occurs in portions of Montana, Wyoming, Idaho, Utah, and Nevada (Hein, et al., 2004). The origin of the phosphate deposits of the Western Phosphate Field is that of basin-wide deposition of phosphate rich sediments, and the location of the P4 deposits is in the approximate center of the basin. This style of mineralization is in contrast to many types of metal deposits that are the result of secondary and more localized geologic processes that are commonly associated with faulting and igneous activity. The faulting in the Western Phosphate Field occurred after ore formation and had no effect on the emplacement of the mineralization; however, it did displace formerly contiguous ore beds. Because of the style of mineralization, changes in the phosphate mineralization occur more gradually on a basin-wide scale (Perkins and Piper, 2004). The character the ore-bearing Phosphoria Formation does not change significantly over a few miles, except possibly along the basin edges, in contrast to other types of ore deposits. This provides somewhat greater latitude in locating comparable background areas in the local region. The Phosphoria Formation geology and geochemistry is not expected to change significantly over a scale of a few miles. Both background areas selected for this study are within 10 miles of the Sites and have been characterized as having similar geology.

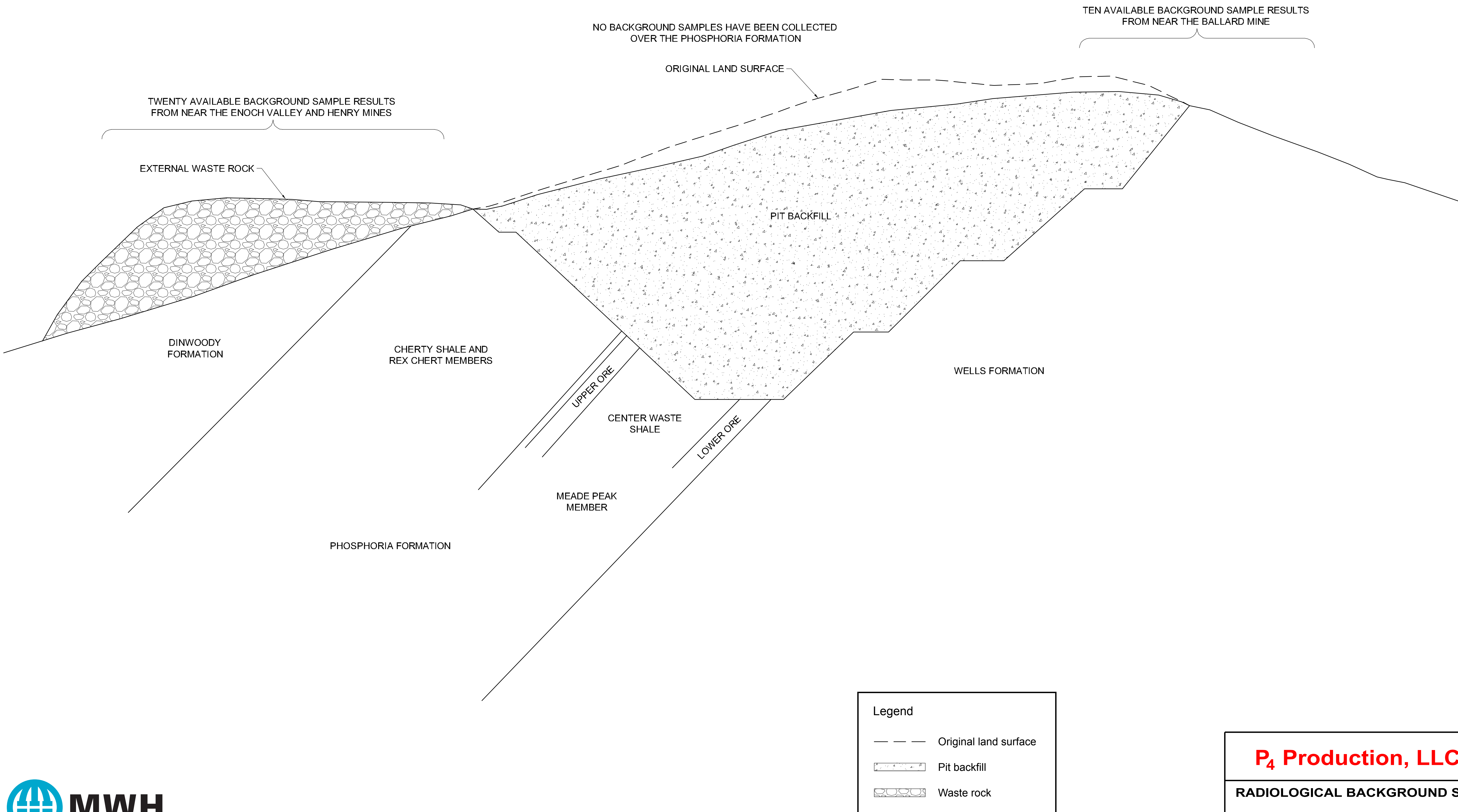
A second criterion of background selection is that the area should be similar to the mined areas, but in an undisturbed condition. Areas immediately adjacent to former or current mines generally to not exist because, if they were similar geologically, they would have been incorporated into the mine (unless there was a property ownership issue or physical constraint). However, the more common reason for the limits of mining is a change in geology (e.g., presence of a fault) that limited the extent of the Phosphoria Formation. In addition, areas adjacent to former or current mining are more likely to have been disturbed. For this reason, locations immediately adjacent to the Sites are not viable.

Ideally, the background area is one that has been identified for future mining, is nearby the P4 CERCLA mines, and has the characteristics of the Sites with similar geologic and topographic configurations. The proposed background areas have been identified for future mining. This helps provide assurance that the proposed background locations have been characterized geologically the extent necessary for comparison to the P4 mines. Both of the locations selected for this background study have been identified for future mining and have ore grade mineralization (within the Phosphoria Formation) at or near the surface (i.e., covered with colluvium) much like the pre-mined Henry and Enoch Valley mine sites.

These proposed areas have well understood geology through surface and subsurface mapping that has been accomplished by drilling (although the data currently are not available). The geologic sequence in both areas consists of moderately to steeply dipping beds of the entire geologic sequence of interest, and this sequence is very similar to the Henry and Enoch Valley Mine geology. At the proposed Blackfoot Bridge background location, the geologic units (beds/formations) are near vertical and the sampling will occur over a relatively short horizontal distance on the ground when compared to the Caldwell Canyon sampling area. This is because at Caldwell Canyon stata dips more shallowly (15-20%), which results in a wider sampling footprint.
The third criterion is the practical considerations of access. Both ownership and physical access are factors that need to be considered. Both factors can be addressed given enough time through agreements and road construction. However, for both proposed background areas, P4 has ownership and physical access for the investigation to proceed.

2.2.4 Facility Maps

Figure 2-2 through Figure 2-10 are provided in support of the DQOs. Figure 2-2 depicts a typical mine cross section and shows the geologic section that is mined and where the waste rock typically is dumped down slope of the excavated ore body. The proposed background area geologic map and aerial photo in Caldwell Canyon and two likely areas for the proposed investigations are depicted on Figures 2-3 to 2-5. Example locations for soil sample collection and radiologic measurements in the Caldwell Canyon Background Area are depicted in plan view on Figure 2-6. In addition, the overall objectives and specific approaches for collection of measurements and soil samples in the Background Area are summarized in the text associated with this figure. Figures 2-7 to 2-9 depicts the two likely background areas in the unmined Blackfoot Bridge Area. The Conda Mine is located adjacent to the southern end of the planned Blackfoot Bridge mine pits, and because of this, the background areas are located away from the south edge of the planned mine pit. Note that as proposed for the Caldwell Canyon background area, there is a primary area and an alternate area selected. Figure 2-10 depicts the proposed investigations at Enoch Valley Mine as if it was selected for investigation and the text on the figure explains the On-Site sampling approach for each of the units selected for radiologic investigations.



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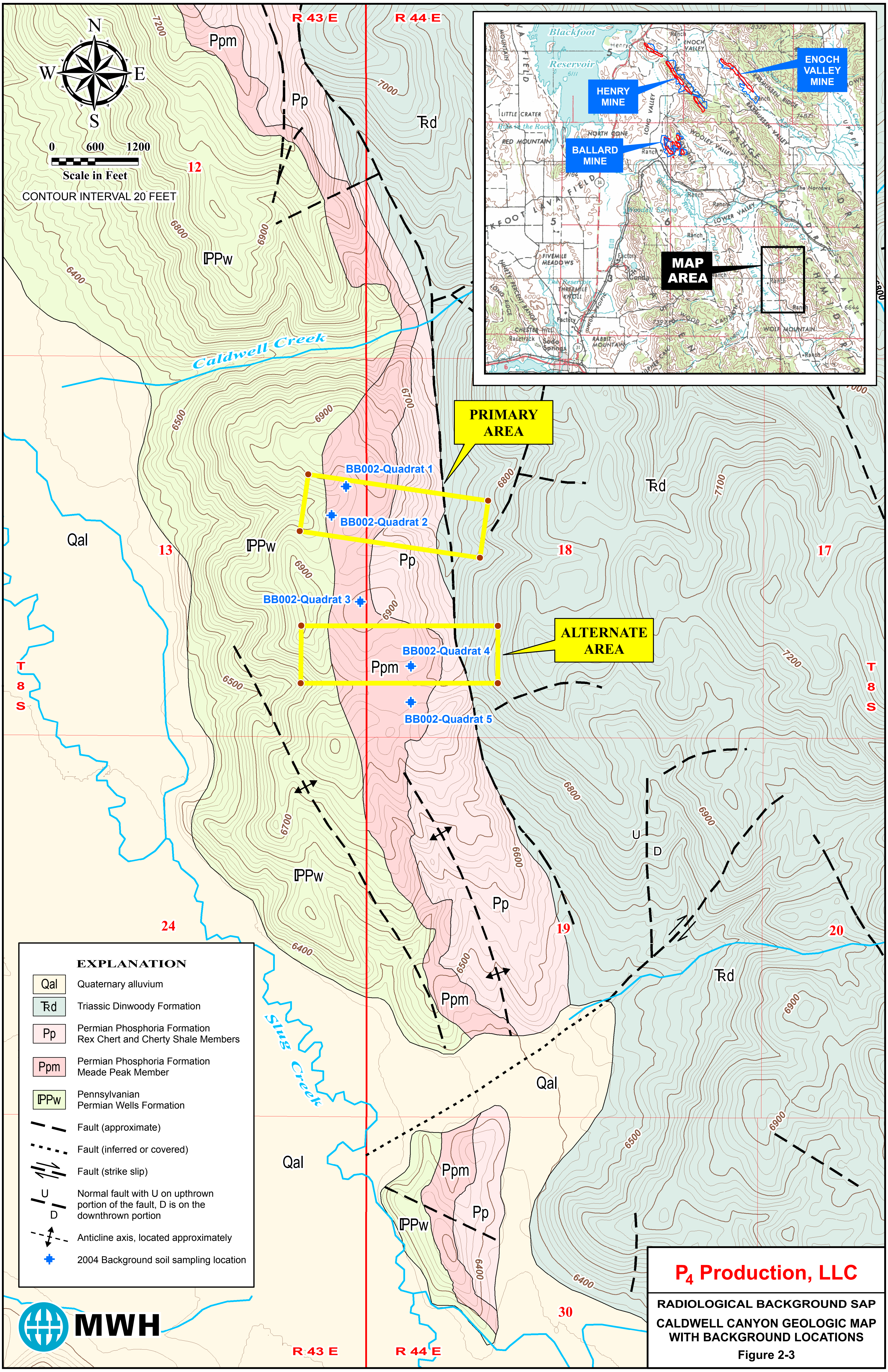
RADIOLOGICAL BACKGROUND SAP

TYPICAL MINE CROSS SECTION

Figure 2-2

FILE Fig 2-2_Typical Mine Cross Section_Feb2014.ai 17 Feb 2014



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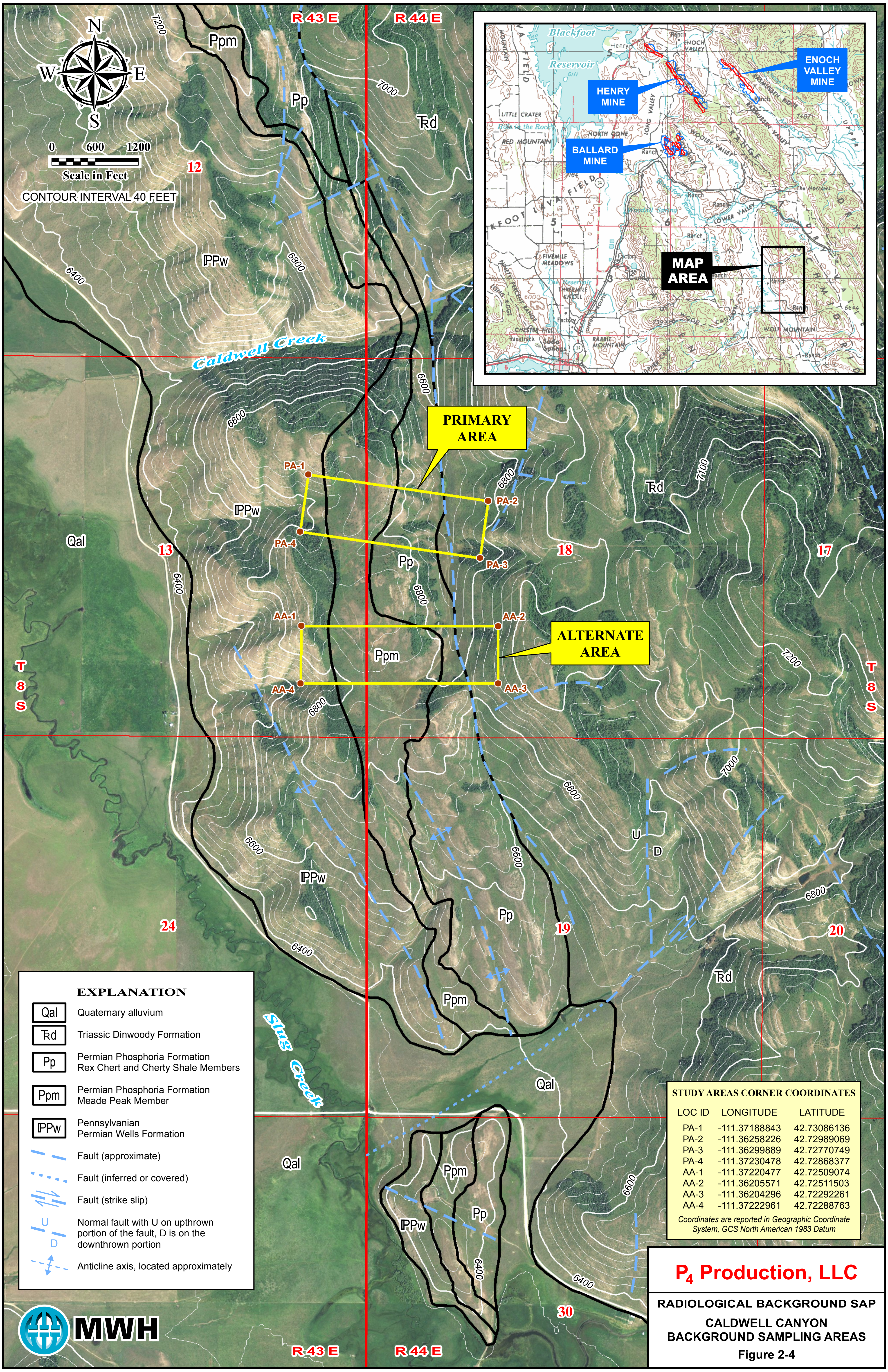
RADIOLOGICAL BACKGROUND SAP

CALDWELL CANYON GEOLOGIC MAP WITH BACKGROUND LOCATIONS

Figure 2-3



STUDY AREAS CORNER COORDINATES

LOC ID	LONGITUDE	LATITUDE
PA-1	-111.37188843	42.73086136
PA-2	-111.36258226	42.72989069
PA-3	-111.36299889	42.72770749
PA-4	-111.37230478	42.72868377
AA-1	-111.37220477	42.72509074
AA-2	-111.36205571	42.72511503
AA-3	-111.36204296	42.72292261
AA-4	-111.37222961	42.72288763

Coordinates are reported in Geographic Coordinate System, GCS North American 1983 Datum

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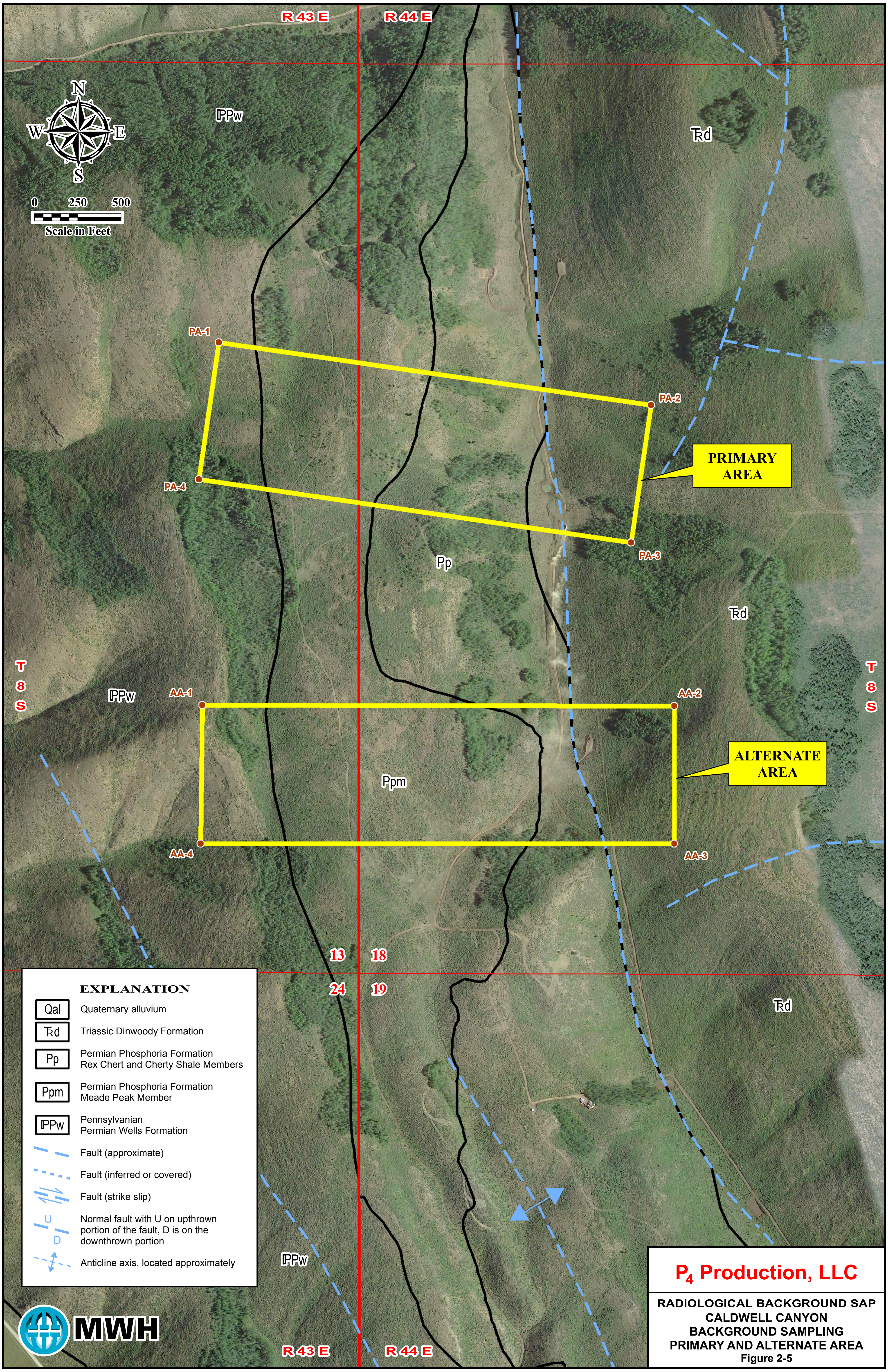

EXPLANATION

Qal	Quaternary alluvium
T̄Rd	Triassic Dinwoody Formation
Pp	Permian Phosphoria Formation Rex Chert and Cherty Shale Members
Ppm	Permian Phosphoria Formation Meade Peak Member
IPPw	Pennsylvanian Permian Wells Formation
	Fault (approximate)
	Fault (inferred or covered)
	Fault (strike slip)
U D	Normal fault with U on upthrown portion of the fault, D is on the downthrown portion
	Anticline axis, located approximately

MWH

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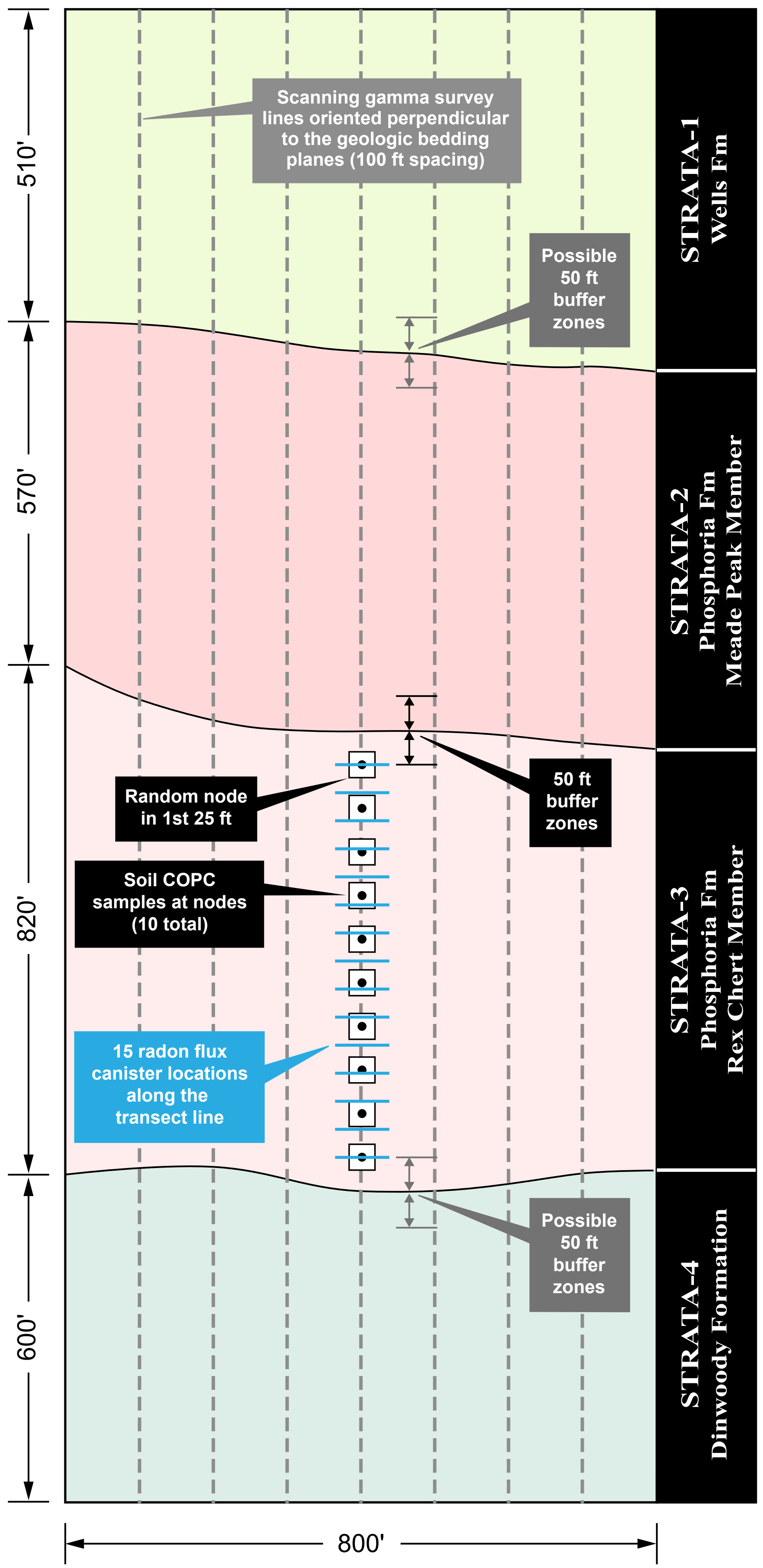
RADIOLOGICAL BACKGROUND SAP
CALDWELL CANYON
BACKGROUND SAMPLING
PRIMARY AND ALTERNATE AREA
Figure 2-5

DRAWN BY D. Severson

15 Jul 2014

PLAN VIEW



NOTE: Sampling shown above will be repeated in each of the strata

"BACKGROUND AREA" SAMPLING OBJECTIVES

- Collection of gamma measurements, through GPS-based gamma surveys, within background reference area that through correlation studies can be used to predict total uranium and Ra-226 concentrations in soil (pCi/g) and exposure rates (µR/hr) or for use in radiological risk evaluations.
- Collection of radon flux measurements that will predict radon air concentrations to calculate background risks posed by radon inhalation exposures to a hypothetical future resident.
- Collection of composite soil samples for analysis of soil COPCs for risk evaluations.
- Collection of composite soil samples for total uranium and Ra-226 and real-time radiological measurements (GPS-based surveys, static gamma counts, and exposure rates) for correlation purposes, to confirm secular equilibrium, improve the robustness of the existing background data sets, and for risk evaluations.

SAMPLING APPROACH

1) Conduct reconnaissance of two survey units (primary and alternate) within Caldwell Canyon, decide on which one to use based on access, terrain, and geology (refer to Figure 2-3).

2) Conduct a GPS-based scanning gamma survey on foot or by ATV over the entire ~800 ft x 2,500 ft Background Area by establishing transect lines oriented perpendicular to the geologic bedding. There will be a 100 foot spacing between these lines.

3) Select a single transect across the Background Area (established in Step 2) that is oriented perpendicular to the geologic units (based on geology and information from Steps 1 and 2) that will be used to collect samples in Steps 4 and 5 below. Based on understanding of the major geologic units, anticipate that there will be a survey area corresponding to each geologic unit[(1)] in the Background Area. Note that only the Rex Chert sampling is depicted on this figure and there are three other areas to be evaluated.

4) ***Radon Flux Canister Sampling:*** Along the transect established in Step 3, install and retrieve a minimum of 15 activated charcoal radon flux canisters (randomly located) per area for a total of 60 locations at sampling nodes (points).
    a. Establish the initial sampling node for each survey area by selecting a random point in the first 25 feet away from geologic contact using a 50 foot buffer zone.
    b. For contacts that are well defined either by backhoe pit or geologic contact information (e.g., presence of Grandeur Tongue Fm which demarks the top of the Wells Fm), a 50 foot buffer zone is not necessary.
    c. Follow-up node spacing (in feet) along transect equals remaining geologic unit thickness (minus the possible 50 foot buffer zones at opposite ends of the geologic unit, then divide by 14.
    d. Establish the actual sample location along a line 50 ft to either side of the node (i.e., parallel to the geologic bedding); use random numbers generated by calculator/computer (0-100 ft).

5) ***Soil COPC[(2)] Sampling:*** Along the transect established in Step 3, collect soil samples per geologic unit (five in Wells Fm, 10 in each of the Phosphoria Fm members) for analysis of soil COPCs at sampling nodes. Five soil samples from the Dinwoody Fm will be collected for comparative purposes.
    a. Use the same initial sampling node for each survey area as established in Step 4a.
    b. Follow-up node spacing along transect equals the remaining geologic unit thickness divided by the nine or four (the remaining samples to be collected)
    c. Collect a composite soil sample for COPC metals using a 50 x 50 ft area centered on the sampling node and five randomly selected grab soil samples composited into one sample.

6) ***Correlation Studies[(3)]:*** Select a minimum of five locations spanning the range of count rates observed from the four survey areas (geologic units) to make simultaneous measurements for the correlations. At each of these selected locations:
    a. Make co-located static gamma (one minute integrated count) and exposure rate measurements (HPIC - three minute average with measurements recovered every six seconds)
    b. Conduct a GPS-based gamma survey of a 1,075 ft^2 (100 m^2) area and collect a five point composite surface soil sample for analysis of total uranium, Ra-226, K-40, and Th-232 concentrations

Footnotes:

(1) Geologic units in the gamma scan area include: Wells Formation, the Meade Peak and Rex Chert/Cherty Sale Members of the Phosphoria Formation, and the Dinwoody Formation, which represent the areas either mined or covered by mine waste rock at the Sites.

(2) Soil COPCs include: antimony, arsenic, boron, cadmium, chromium, cobalt, copper, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, uranium, vanadium, and zinc.

(3) These judgmental soil samples are not depicted on the plan view detail (see left), but will be selected in the field based on the range of the gamma survey count rates.

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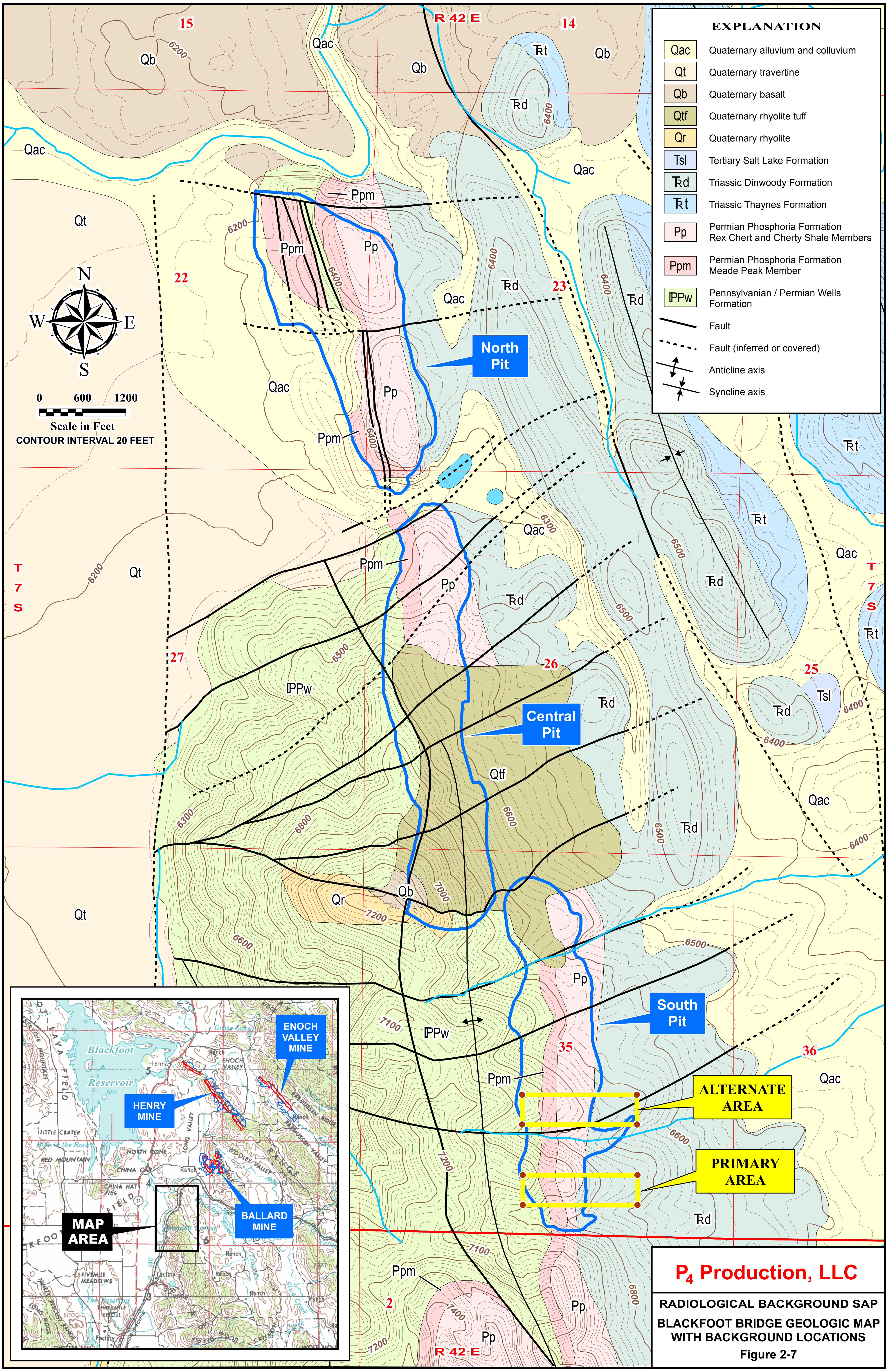
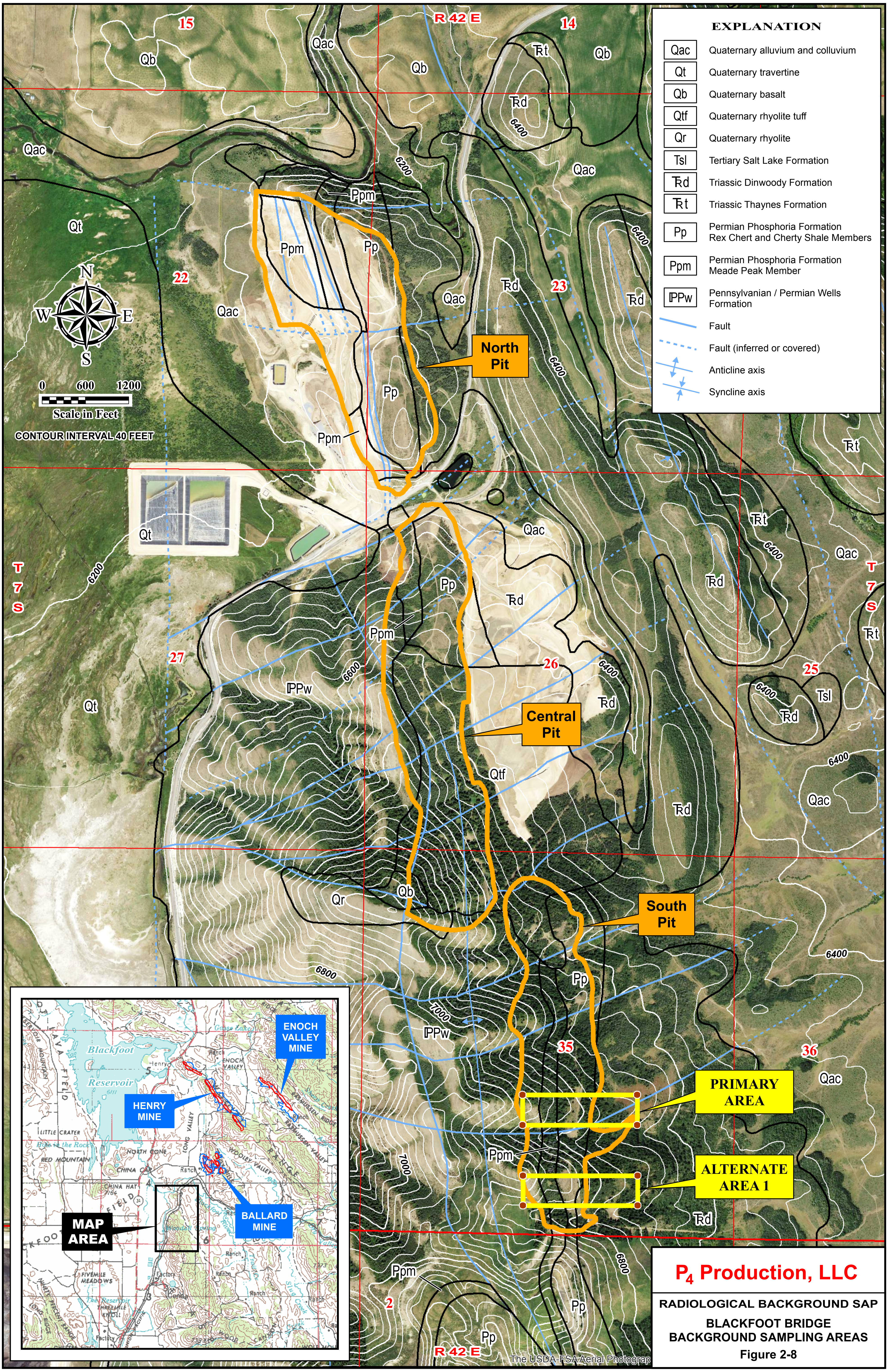
RADIOLOGICAL BACKGROUND SAP

BACKGROUND AREA PLAN VIEW AND SAMPLING APPROACH

Figure 2-6

Fig 2-6_BackgroundAreaPlanView_Approach_Jul2014_MOD1.ai


EXPLANATION
Qac Quaternary alluvium and colluvium
Qt Quaternary travertine
Qb Quaternary basalt
Qtf Quaternary rhyolite tuff
Qr Quaternary rhyolite
Tsl Tertiary Salt Lake Formation
₮d Triassic Dinwoody Formation
₮t Triassic Thaynes Formation
Pp Permian Phosphoria Formation Rex Chert and Cherty Shale Members
Ppm Permian Phosphoria Formation Meade Peak Member
IPPw Pennsylvanian / Permian Wells Formation
Fault
Fault (inferred or covered)
Anticline axis
Syncline axis
N
W
E
S
0 600 1200
Scale in Feet
CONTOUR INTERVAL 20 FEET
R 42 E
T 7 S
15
14
22
23
27
26
25
35
36
2
North Pit
Central Pit
South Pit
ALTERNATE AREA
PRIMARY AREA
ENOCH VALLEY MINE
HENRY MINE
BALLARD MINE
MAP AREA
Blackfoot Reservoir
P4 Production, LLC
RADIOLOGICAL BACKGROUND SAP
BLACKFOOT BRIDGE GEOLOGIC MAP WITH BACKGROUND LOCATIONS
Figure 2-7



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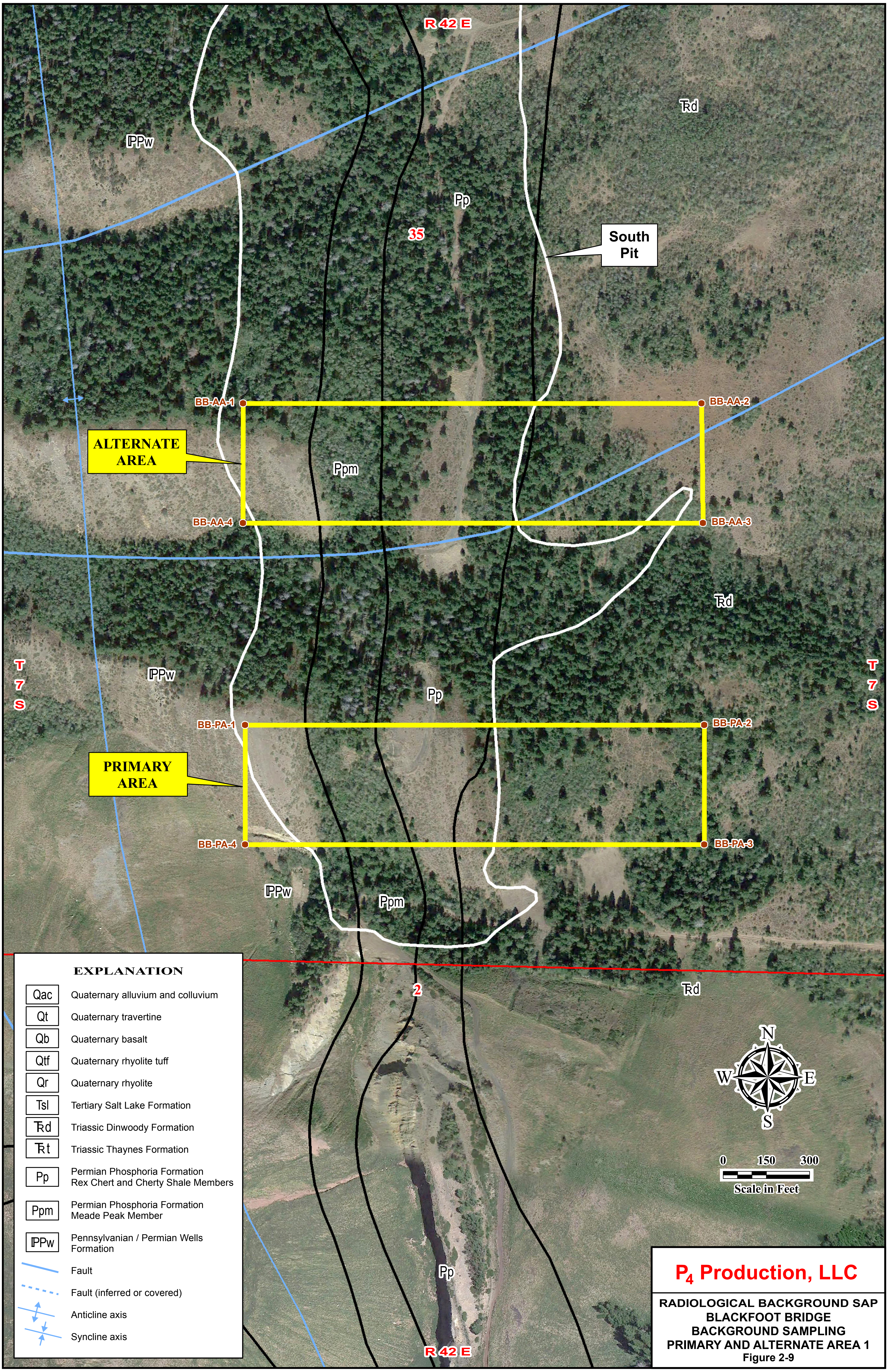
RADIOLOGICAL BACKGROUND SAP

BLACKFOOT BRIDGE BACKGROUND SAMPLING AREAS

Figure 2-8

FILE: D:\MWH\P4 Monsanto\P4 Radiological Background SAP_Feb2014\FIGURES_AUG2014\Fig 2-9_Monsanto_Blackfoot Bridge_Background_PA_AA_Aug2014.mxd 30 Jul 2014 DRAWN BY D. Severson



"ON-SITE" SAMPLING OBJECTIVES

- Collection of gamma measurements, through GPS-based gamma surveys, focused on the source areas (waste rock dumps) within the Ballard, Henry and Enoch Valley Mines that through correlation studies can be used to predict total uranium and Ra-226 concentrations in soil (pCi/g) and exposure rates (µR/hr) or for use in radiological risk evaluations.
- Collection of radon flux measurements that will predict radon air concentrations to calculate background risks posed by radon inhalation exposures to a hypothetical future resident.
- Collection of composite soil samples for total uranium and Ra-226 and real-time radiological measurements (GPS-based surveys, static gamma count, and exposure rates) for correlation purposes, to confirm secular equilibrium, improve the robustness of the existing background data sets, and for risk evaluations.

SAMPLING APPROACH

1) Conduct reconnaissance and a GPS-based gamma survey primarily over the disturbed portions (i.e., waste rock dumps) of each of the three mines (using a 200-foot spacing). Survey transects will extend approximately 200 ft off the waste rock dumps.

2) Define distinct survey areas based on the GPS-based gamma survey results and mines site conditions from Step 1. Anticipate, based on understanding of mine site reclamation, that there will be distinct survey areas identified in and/or between the P4 Sites. Select a total of three survey units/areas throughout the mines, as identified by the GPS-based gamma survey (low, medium, and high gamma count rates), for correlation studies (representing different mine reclamation conditions).

3) ***Radon Flux Canister Sampling:***

   Select three major survey areas which will span the range of gamma count rates (low, medium, and high,) and likely represent different reclamation conditions as discussed above) based on the GPS-based gamma survey throughout the Sites.

   a. Install and retrieve 15 randomly-located activated charcoal radon flux canisters per selected survey area (for a total of 45 radon flux samples).

   b. Divide each of these major survey areas into 15 approximately equal subareas by dividing the total area (ft^2) by the number of samples to be collected (i.e., 15 radon canister samples).

   c. In each of these 15 subareas, select a point randomly for sampling by estimating their horizontal dimensions and randomly selecting the locations for placement of the radon flux canisters.

4) ***Correlation Studies [(1)]:***

   Select a minimum of 10 locations spanning the range of count rates observed from the three survey areas (low, medium, and high) to make simultaneous measurements for the correlations. At each of these selected locations:

   a. Make co-located static gamma (one minute integrated count) and exposure rate measurements (HPIC - three minute average with measurements recovered every six seconds)

   b. Conduct a GPS-based gamma survey of a 1,075 square ft^2 (100 m^2) area and collect a five point composite surface soil sample soil sample for analysis of total uranium, Ra-226, K-40, and Th-232 concentrations.

5) No additional sampling for soil COPCs is proposed On-Site.

FOOTNOTE:

(1) These judgmental soil samples are not depicted on the plan view detail (see left), but will be selected in the field based on the range of the gamma survey count rates.

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RADIOLOGICAL BACKGROUND SAP

HYPOTHETICAL ON-SITE SAMPLING APPROACH AT ENOCH VALLEY MINE

Figure 2-10

DRAWN BY D. Severson

30 Jul 2014

D:\MWH\P4 Monsanto\P4 Radiological Background SAP_Feb2014\FIGURES_AUG2014\Fig 2-10_Hypothetical Onsite Sampling Approach_Aug2014.mxd

3.0 SAMPLING DESIGN – BACKGROUND AND ON-SITE AREAS

The overall sampling objectives and rationale for sample collection varies somewhat between the Background and On-Site Areas. The text on Figure 2-6 and Figure 2-10 explains the sampling objectives and rationale for the Background and On-Site Areas as further described below and Table 3-1 summarizes the number of samples, location, and analytical parameters. Detailed objectives of the data collection activities are provided in Section 1.2. Additional data will be collected from: (1) two Background Areas that are representative of pre-mining conditions and (2) from selected areas within the Sites that include a variety of reclamation conditions on the waste rock dumps and encompass a range of potential radiological exposure (low, medium, and high). This section describes the sampling design (i.e., approach and rationale) necessary for collection of these data. The FSP and QAPP in Appendices A and B provide details regarding the equipment and procedures that will be used in the field to collect these samples and measurements.

The primary radiogenic human health risk drivers at the Sites are exposure to radon gas and radiation dose from direct exposure to gamma or ingestion of abiotic media or biota containing radionuclides. The data needed to evaluate risks from these parameters are external gamma, radon flux, exposure rates, and soil concentrations of total uranium and daughters products (e.g., Ra-226). The following field and laboratory analytical methods will be used to collect these data:

- Scanning GPS-based gamma survey (counts per minute) using a sodium iodide (NaI) high energy gamma detector
- Static gamma count rate (counts per minute) using the same NaI detection system
- Radon flux measurements (pCi/m^2s) using charcoal canisters in accordance with USEPA Method 115 (40 CFR Part 61)
- Exposure rates using an HPIC (microRoentgens per hour [μR/hr], which is largely equivalent to a dose rate, in microrem per hour [μrem/hr])

- Total uranium (mg/kg; USEPA 6020A) and Ra-226, Th-232, and K-40 concentrations in soil (pCi/g; Gamma Spectroscopy Analysis by EPA 901.1M)
- Soil samples for other COPCs in soil (mg/kg) will be collected from the Background Areas for analysis by USEPA Methods 6020A and 7471A

Soil samples will be collected concurrently with the radiological surveys to: (1) simplify the field sampling program, (2) ensure efficient data collection, and most importantly, (3) allow for correlations between the scanning gamma survey and the radiologic parameters listed above. Actual field measurements and sample locations in a "typical" Background Area and On-Site Area are shown and described in Figures 2-6 and 2-10, respectively.

3.1 Background Area Sampling Approach

In contrast to the waste rock areas of the Sites, characterized by a random mixture of rock types, variable lithologies and likely radiological makeup, the Background Areas contain a stratified sequence of rock that is in an unmined, natural state. This stratified sequence is best sampled by traversing the sequence perpendicular to the strike of the strata (i.e., perpendicular to the bedding). In this way, all of the representative lithologies are included in the background sampling. Below are the steps that will be conducted in each of the Background Areas to complete the radiological and soil COPC investigations. Figure 2-6 depicts the plan view of the selected Caldwell Canyon area and presents graphically and in legend descriptions the procedures that will be employed to collect radiological measurements and soil samples in the Background Areas.

1) Conduct reconnaissance of two survey units (primary and alternate) at both of the Caldwell Canyon and Blackfoot Bridge areas, decide on which one (primary or alternate) to use based on access, terrain, and geology. Refer to Figures 2-3 to 2-5 and 2-7 to 2-9 for the locations of the primary and alternate areas at Caldwell Canyon and Blackfoot Bridge.

2) Conduct a GPS-based gamma survey over the entire ~800 feet (ft) x 2,500 ft background reference area by establishing transect lines oriented perpendicular to the geologic bedding with a 100-foot spacing between the lines. The same procedures used in the Caldwell Canyon Background Area will be repeated in the Blackfoot Bridge Background Area (refer to Figure 2-7). Note: If elevated gamma readings occur when scanning the Wells Formation within the Blackfoot Bridge primary survey area (due to proximity of J.R. Simplot operations), then scanning and sampling of the Wells Formation in the alternate area will be performed.
3) Select a single line of transect across the Background Area that is oriented perpendicular to the geologic units (based on geology and information from Steps 1 and 2) that will be used to collect samples in Steps 4 and 5, below. Based on understanding of the major geologic units, anticipate that there will be four survey areas corresponding to the four geologic units in the Background Area. Note that in Figure 2-6 only the Rex Chert sampling event is depicted and there will be three others in the other geologic units. Geologic units in the areas include: (1) uppermost Wells Formation; (2) Dinwoody Formation; and (3) the Meade Peak and (4) Rex Chert/Cherty Shale Members of Phosphoria Formation. (The Rex Chert and Cherty Shale Members are grouped together as one unit.) These geologic units represent the sequence of rock and soil most commonly either mined or covered by mine waste rock at the Sites. The survey lines (areas) will be chosen based on (1) the gamma survey results, which should clearly show the Meade Peak Member's upper and lower contacts and (2) favorable field conditions including: changes in the dominant formation (i.e., formation contacts), vegetation coverage (areas with sparse of trees/scrubs cover would be desired), accessibility by all-terrain vehicles, etc. The transect survey lines crossing areas that are overly steep or have bedrock outcrops would be avoided.

It is assumed that most areas will contain locally-derived colluvial soils, which are representative of the Sites in a pre-mined or native condition. No attempt will be made to specifically separate colluvial from in-place soils. It is assumed that because of similar topography and terrain steepness in the background areas and at the former mine Sites, the soil forming and mass movement processes are similar between the locations. For example, the terrain at the Sites range from flat to moderately steep, often within a single mine area like south and north Enoch Valley, and the background areas generally represent an average condition.

In addition, soil samples will not be collected within 50 feet of the geologic contact between the Rex Chert Member and the Meade Peak Member due to uncertainty in this contact. However, the contact between the Wells Formation and Meade Peak Member is generally identifiable due to the resistant nature of the Grandeur Tongue Formation; however, a 50 foot buffer also may be applied if there is uncertainty with the location of the contact. Soil samples also will not be collected from rock outcrops themselves, but the in-place, colluvial soils that overlie each of the formations.

4) ***Radon Flux Measurements:*** In each Background Area, along the transect established in Step 3, a minimum of 15 activated charcoal radon flux canisters (randomly located) will be installed and retrieved from each of the four survey areas for a total of 60 locations at sampling nodes (points).

5) ***Soil COPC Sampling:*** In each of the Background Areas, the geologic units to be sampled for soil COPCs will include: (1) the Meade Peak Member of the Phosphoria Formation, (2) the Rex Chert/Cherty Shale Members of the Phosphoria Formation, and (3) the Wells Formation. Background data for soil COPCs is available for the Wells and Dinwoody Formations from the 2009 Soil and Vegetation program (MWH, 2011 and MWH, 2013b). During that investigation, 20 soil samples were collected from the Dinwoody Formation and 10 soil samples were collected from the Wells Formation.

   In order to have a similar number of soil samples from each of the geologic units, 10 additional soil samples will be collected from the Wells Formation (five soil samples from each Background Area); 20 soil samples will be collected from the Rex Chert Member (10 soil samples from each Background Area); and 20 soil samples from the Meade Peak Members of the Phosphoria (10 soil samples from each Background Area).

This will result in the following:

a. 20 soil samples from the Dinwoody Formation (collected in 2009)
b. 20 soil samples from the Meade Peak member of the Phosphoria Formation (collected in 2014)
c. 20 soil samples from the Rex Chert/Cherty Shale Members of the Phosphoria Formation (collected in 2014)
d. 20 soil samples from the Wells Formation (10 soil samples collected in 2009 and 10 soil samples collected in 2014)

In addition, P4 will collect ten (10) additional samples for the Dinwoody Formation using the same sampling procedures as used for the samples listed above. Five (5) samples will be collected at each of the background areas. These samples will be used for qualitative comparison to the previous Dinwoody Formation samples collected the Henry and Enoch Valley Mines. However, they will be excluded from the background data set in favor of the Henry and Enoch Valley samples collected in 2009.

Field personnel will collect composite soil samples from each of the geologic formations discussed above as described in the FSP (Appendix A).

Correlation Studies: In each of the two Background Areas, select a minimum of five locations spanning the range of count rates observed from the GPS-based gamma survey areas/units (i.e., the four geologic units depicted in Figures 2-3 and 2-7) and collect measurements for the correlations (i.e., a minimum of 10 locations from the Background Areas) as described below.

At each of the selected correlation locations:

a. Collect co-located direct gamma count (one minute integrated count) and exposure rate measurements made every six seconds for three minutes, using a high pressure ionization chamber [HPIC].
b. Conduct a GPS-based survey of a 1,075 square ft (ft^2) (100 square meter [m^2]) area and collect a five point composite surface soil sample therein, for analysis of total uranium, Ra-226, K-40, and Th-232 concentrations.

3.2 On-Site Sampling Approach

The assumed area of disturbance for the Ballard, Henry, and Enoch Valley Mine Areas are 534, 969, and 498 acres, respectively or a total of approximately 2000 acres (MWH, 2011). The On-Site sampling approach involves the following steps:

1) Conduct reconnaissance and a GPS-based gamma survey primarily over the disturbed portions (i.e., waste rock dumps) of each of the three mines (using a 200-foot spacing). Survey transects will extend approximately 200 feet off the waste rock dumps to confirm that the radiologic materials are confined in and near the dumps and have not spread.
2) Define size and location of distinct survey areas based on the GPS-based gamma survey results and mines site conditions from Step 1. Anticipate, based on the understanding of mine site reclamation, that there will be distinct survey areas identified in and/or between the Sites. Select a total of three survey units/areas throughout the P4 Site, as identified by the GPS-based gamma survey (low, medium, and high gamma count rates). The survey areas may or may not include all three P4 Mine Sites (e.g., two survey areas at the Ballard Mine and one survey area at the Enoch Valley Mine). Figure 2-10 depicts a hypothetical "unit" selected for investigation at the Enoch Valley Mine and discusses the sampling objectives and approach.
3) ***Radon Flux Measurements:*** In each of the three major survey areas (low, medium, and high gamma count range identified in Step 2), install and retrieve 15

randomly-located activated charcoal radon flux canisters per selected survey area (for a total of 45 radon flux measurements).

4) ***Correlation Studies:*** Similar to the correlation studies in the Background Areas, select a minimum of 10 locations spanning the range of gamma count rates across the three selected units (identified in Step 2), then perform a GPS-based gamma survey and collect co-located gamma count and exposure rate measurements and five point composite soil samples for the correlations. At each of these selected correlation locations:
   a. Collect co-located direct gamma count (one minute integrated count) and exposure rate measurements made every six seconds for three minutes, using a HPIC.
   b. Conduct a GPS-based survey of a 1,075 ft^2 (100 m^2) area and collect a five point composite surface soil sample for analysis of total uranium, Ra-226, K-40, and Th-232 concentrations.

5) No additional sampling for soil COPCs is proposed On-Site.

3.3 Summary of Sampling Methods and Rationale

The FSP in Appendix A includes the detailed methods and procedures to be used when each activity is conducted during the Background Areas and On-Site investigations. The activities summarized in the FSP are as follows and summarized below.

- Reconnaissance Field Survey (Background Areas only)
- GPS-based Gamma Survey
- Radon Flux Measurements
- Correlation Studies
- Soil COPCs Sampling (Background Areas only)

3.3.1 Reconnaissance Field Survey

A reconnaissance field survey will be conducted at both background locations and at the Sites. The identified potential Background Areas are representative of the typical width of a phosphate mine footprint such as the Henry or Enoch Valley Mines (approximately 1,000 to 2,000 feet from the ridge to the valley below). A reconnaissance field survey of two background areas (primary and alternate) within both the proposed Caldwell Canyon and Blackfoot Bridge background areas will be conducted to decide which one (the primary or alternate) to use based on access, terrain, and geology. A field survey, as discussed above in the potential background areas, will not be necessary in the On-Site Areas. In addition, it is anticipated that test pits will be performed by P4 in the Caldwell Canyon Area. These test pits will be used to assist identification of geologic contacts.

3.3.2 GPS-Based Gamma Survey

For large areas, such as the Background and On-Site Areas, gamma emissions are best characterized by conducting GPS-based gamma surveys, in which gamma emissions and geopositions are measured and recorded in real-time while field personnel move across the site.

Site-wide exposure rates and Ra-226 concentrations can be predicted from the data obtained in the GPS-based gamma survey by correlating the gamma count to exposure rates and Ra-226 and uranium concentrations in soil, using the methods described in Section 3.3.4 below. Maps of the predicted exposure rates and Ra-226 and uranium concentrations can be generated using a geographic information systems software, or equivalent.

Exposure rate maps created in this manner are relatively inexpensive and provide a good estimate of the direct radiation dose posed to a potential residential occupant in the risk assessment. These maps also provide a good indication of the Ra-226 in the top layer of soil and may correlate with the radon flux when the top 10-ft layer of material is relatively homogeneous. The surface exposure rate maps also can be used to select soil sampling locations to capture the range of the parameter values at the Sites. For specific equipment and procedures to be used during the GPS-based gamma survey, refer to the FSP in Appendix A and its associated standard operating procedures (SOPs) in Attachment A.

3.3.3 Radon Flux Measurements

Fifteen activated charcoal radon flux canisters will be placed on each of the study areas/units identified in both Background Areas (four geologic-formation study areas) and at the Sites (three study areas). Thus, during the study a total of 165 radon flux measurements will be collected. Fifteen is a reasonable number of samples per study area based on the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) approach of determining the number of samples for statistical analysis assuming a Type 1 and 2 error rate of five percent (Table 5-3; NRC, 2000). Equipment and procedures to be used in the collection of radon flux measurements is detailed in Appendix A of the FSP (and its associated SOPs).

The flux measurements, reported in units of pCi m^2/s, will be used to estimate radon concentrations in indoor and outdoor air using methods published in "Source and Effects of Ionizing Radiation, Volume I" (United Nations Scientific Committee on the Effects of Atomic Radiation [UNSCEAR], 2000), or equivalent. The air concentrations will be incorporated into the portion of the radiological risk assessment devoted to radon exposure.

3.3.4 Correlation Studies

Correlation studies are necessary so that information collected through the GPS-based gamma survey can be translated to Site-wide, predicted exposure rates and Ra-226 and uranium concentrations for use in the risk assessments. In each of the Background Areas, correlation studies will be conducted across each of the four geologic formations (5 in each background area). A total of ten (10) On-Site correlation studies are anticipated in areas identified in the GPS-based gamma survey (low, medium, and high), which likely represent different mine reclamation conditions. Therefore, a minimum of 20 correlations locations will be selected across the Background and On-Site Areas. This will include the five (5) correlation samples collected in each of the two Background Areas for a total of ten (10) correlation samples from the Background Areas plus ten (10) On-Site samples.

The following activities will be conducted at each of the correlation sites:

- **Co-located Direct (Static) Gamma Count and Exposure Rate Measurements** Co-located Direct (static) gamma and exposure rate measurements will be made at locations identified based on the GPS-based gamma survey results. Measurements will be made according to the methods detailed in Attachment A to the FSP.

- **GPS-Based Gamma Surveys and Composite Soil Sampling** – GPS-based gamma surveys and composite soil sampling will be conducted at each of the locations to develop a correlation between Ra-226 concentrations in surface soil and gamma count rates. The composite approach was chosen over a point measurement approach to reduce variability in the correlation analysis. The average gamma count rate over the correlation area will be correlated to Ra-226 concentrations, using the linear regression feature of MS Excel, or equivalent.

3.3.5 COPC Soil Sampling in Background Areas

Soil samples representative of background conditions for COPCs in soil will be collected in both of the Background Areas (Caldwell Canyon and Blackfoot Bridge). Soil samples from the Sites for analysis of COPC concentrations will not be collected as part of this SAP, because enough on-Site soil data already exist for risk evaluations. The soil overlying specific geologic formations will be the focus of background COPC sampling. This will include soils from over the Meade Peak and Rex Chert/Cherty Shale Members of the Phosphoria Formation (i.e., formal geologic members of the Phosphoria Formation or strata). Soils overlying the Wells Formation will also be sampled. Background data for soil COPCs are already available for the Wells and Dinwoody Formations from the 2009 Soil and Vegetation program (MWH, 2013b); however, in order to have an equal number of samples from each geologic unit, additional soil samples are required from over the Wells Formation. In addition, as presented in Section 3.1, an additional ten (10) samples will be collected from the Dinwoody Formation for qualitative comparison between background areas. These additional samples will not be included in the background data set in favor of the 2009 soil samples collected within the Sites.

In each of the two Background Areas, 10 randomly-selected composite samples will be collected from soil overlying each of the Phosphoria Formation geologic units (Meade Peak and Rex Chert), and five (5) randomly-selected composite samples will be collected from soil overlying the Wells Formation. So, in each of the Background Areas, a total of 25 composite samples representative of the three geologic formations will be collected for analysis (a total of 50 composite samples from the two Background Areas).

The above sampling approach will result in the following background sample population:

- 20 soil samples from the Dinwoody Formation (collected in 2009)
- 20 soil samples from the Meade Peak member of the Phosphoria Formation (collected in 2014)
- 20 soil samples from the Rex Chert/Cherty Shale Members of the Phosphoria Formation (collected in 2014)
- 20 soil samples from the Wells Formation (10 soil samples collected in 2009 and 10 soil samples collected in 2014).

The background soil samples collected for COPC analyses from soil overlying each of the geologic formations during this sampling effort will be evaluated consistent with the statistical methods and procedures detailed in the *Background Levels Development Technical Memorandum* (MWH, 2013b), which will include performing an outlier analysis and development of summary statistics and statistical limits. The calculated statistical limits (e.g., 95% upper confidence limit on the mean [95% UCL] and 95% upper simultaneous limit [95%USL]) for each COPC in each geologic formation will then be weighted in order to calculate representative background statistical limits for individual COPCs over all geologic formations. The weighting will be based on the stratigraphic thickness of each formation that is affected by phosphate mining (estimated based on the "typical mining footprint" overlaying the geology of the selected Background Areas), as further described below.

The mining operation completely impacts the Meade Peak Member of the Phosphoria Formation as this unit contains the ore. When the Meade Peak Member is mined, the majority (if not all) of the Rex Chert and Cherty Shale Members (Rex Chert/Cherty Shale) of the Phosphoria Formation also are excavated. This is illustrated in Figure 2-2 and the photograph in Figure 3-1. The Rex Chert/Cherty Shale is either removed by mining or is covered by external waste rock placed adjacent to the mine pit and on the downhill side (see the cross-section in Figure 2-2 and geologic map in Figure 3-2). Therefore, mining affects 100% of the Phosphoria Formation members and the soils formed on these units.

The geologic maps for the Lower Valley Quadrangle (Oberlindacher, et al. unpublished), Dry Valley Quadrangle (Cressman and Gulbrandsen, 1955), Henry Quadrangle (Derkey and Palmer, 1984) and the Upper Valley Quadrangle (Rioux, et al., 1975) were evaluated to estimate vertical thickness of these Phosphoria Formation members. From these documents the average stratigraphic thickness of the Phosphoria's Meade Peak Member is estimated at approximately 165 feet. This agrees well with a measured thickness at the Enoch Valley Mine of 170 feet (P4, unpublished). The Rex Chert/Cherty Shale Member is estimated at 250 feet thick.

SOURCE: P4/Monsanto photograph

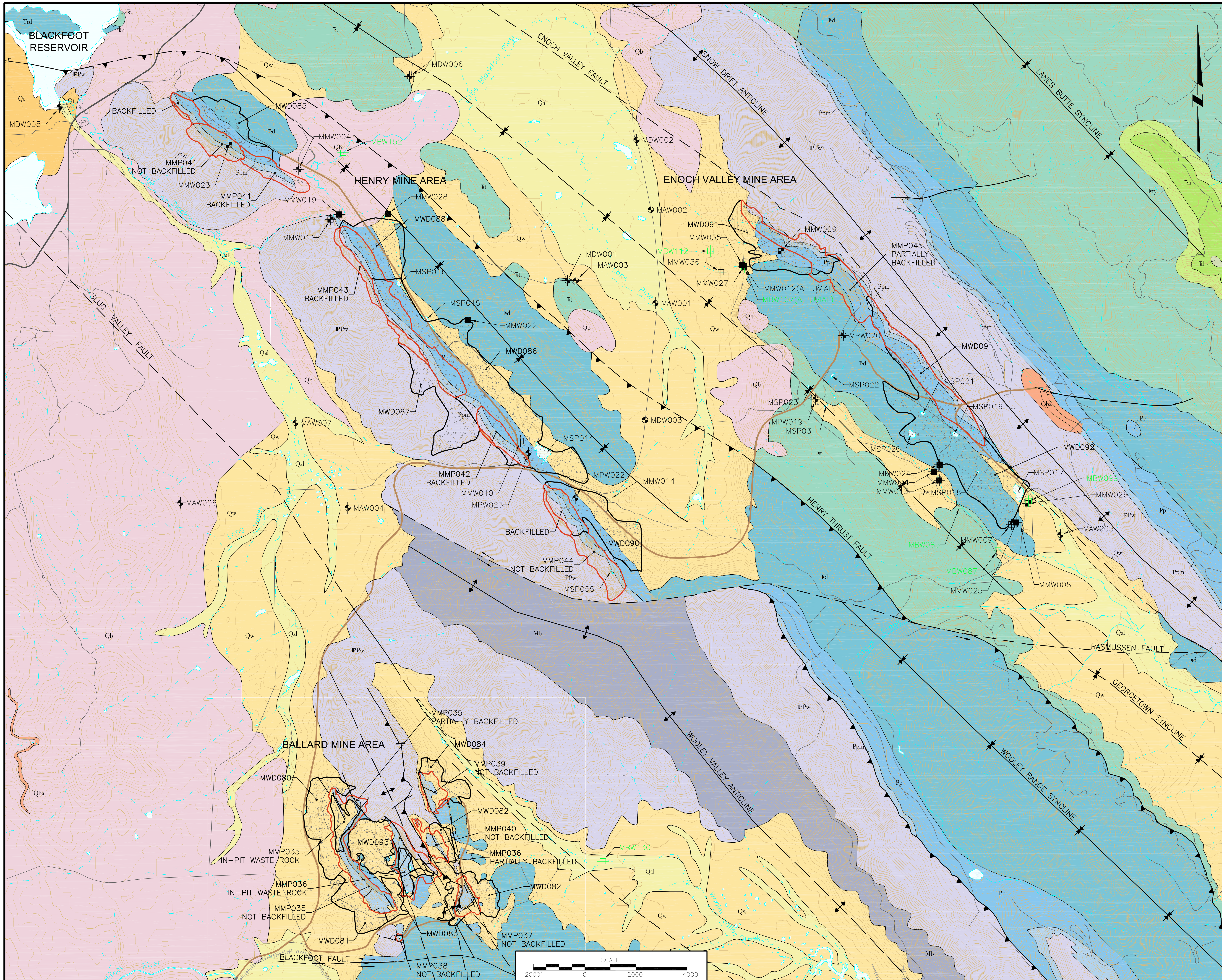
MWH

P$_4$ Production, LLC

RADIOLOGICAL BACKGROUND SAP

ENOCH VALLEY MINE

Figure 3-1



LEGEND:

- POST–MINE CONTOUR AND ELEVATION, FEET (APPROXIMATE)
- RIVER
- POND OR LAKE
- NATURAL DRAINAGE – PERENNIAL
- NATURAL DRAINAGE – INTERMITTENT
- HIGHWAY
- ROAD
- MONSANTO HAUL ROAD (ACTIVE & INACTIVE)
- RAILROAD
- MINE PIT LOCATION (APPROXIMATE WHERE COVERED BY BACKFILL)
- WASTE ROCK DUMP LOCATION (APPROXIMATE)
- WASTE ROCK DUMP LOCATION OR PIT BACKFILL (APPROXIMATE)
- FAULT
- THRUST FAULT (DASHED WHERE INFERRED)
- APPROXIMATE OR INFERRED FAULT
- AXIS SYNCLINE (DASHED WHERE INFERRED)
- AXIS ANTICLINE (DASHED WHERE INFERRED)

STATION TYPE:

- MAW = AGRICULTURAL WELL
- MDW = DOMESTIC WELL
- MPW = PRODUCTION WELL
- MMW = LOCAL AQUIFER MONITORING WELL (GENERALLY ALLUVIAL SYSTEM)
- MMW = INTERMEDIATE AQUIFER MONITORING WELL (GENERALLY DINWOODY FM.)
- MMW = REGIONAL AQUIFER MONITORING WELL (WELLS FM.)
- MMW = AQUIFER MONITORING WELL (UNKNOWN OR MULTIPLE AQUIFERS SCREENED)
- MBW = DIRECT PUSH ALLUVIAL AQUIFER WELL

GEOLOGIC KEY:

- Qb BASALT
- Qba BASALTIC ASH – TUFF
- Qal ALLUVIUM
- Qt TRAVERTINE
- Qw COLLUVIUM AND OLDER ALLUVIUM
- Tkl DEADMAN LIMESTONE
- Th HIGHAM GRIT
- Tt THAYNES FORMATION
- Tty TIMOTHY SANDSTONE – THAYNES MEMBER
- Td DINWOODY FORMATION – WOODSIDE SHALE
- Pp / Ppm PHOSPHORIA FORMATION MEADE PEAK MEMBER
- PPw WELLS FORMATION
- Mb BRAZER LIMESTONE
- Mm MADISON LIMESTONE

KEY:

MMP = MINE PIT
MWD = WASTE ROCK DUMP
MSP = POND

NOTE:

1. GEOLOGIC DATA SOURCES: OBERLINDACHER, ET AL., 1982; HOVLAND, 1981; MANSFIELD, 1927; OBERLINDACHER, 1990. MAP HAS IN PART BEEN UPDATED BASED ON OBERLINDACHER, ET AL., UNPUBLISHED. SHA

ISSUE REV	DESCRIPTION	TECH	ENG	DATE
1	FINAL	CHF	LWM	02/24/11
0	ISSUED DRAFT FOR AGENCY REVIEW	CHF	LWM	07/06/10

DISCLAIMER:
THIS DRAWING WAS DEVELOPED THROUGH THE APPLICATION OF PROFESSIONAL ENGINEERING SKILL AND PROPRIETARY METHODOLOGIES, PROCESSES AND KNOW HOW OF MWH AS AUTHOR ALL PURSUANT TO THE TERMS OF A CONTRACTUAL SCOPE OF WORK GOVERNING ITS PREPARATION. THIS DRAWING MAY NOT BE USED OR MODIFIED OTHER THAN IN STRICT ACCORDANCE WITH THE TERMS OF THE GOVERNING CONTRACT AND SCOPE OF WORK OR OTHERWISE ABSENT THE INVOLVEMENT AND CONSENT OF THE AUTHOR. ANY ALTERATION OR ADAPTATION OF THIS DRAWING SHALL BE CONSISTENT WITH THE AUTHOR'S CONTRACTUAL AND PROPRIETARY RIGHTS AND BE AT USER'S SOLE RISK AND WITHOUT ANY LIABILITY OR LEGAL RESPONSIBILITY OF MWH.

DRAWING REFERENCE(S):
1. POST–MINE TOPOGRAPHY GENERATED FROM:
- USGS DIGITAL ELEVATION MODELS (DEM)–24K.
- SURVEY DATA FOR BALLARD MINE PROVIDED BY OLYMPUS AERIAL SURVEYS, INC. DATED: JUNE 2005.
- SURVEY DATA FOR HENRY MINE AREA PROVIDED BY OLYMPUS AERIAL SURVEYS, INC. DATED: NOVEMBER 2008.
- SURVEY DATA FOR ENOCH VALLEY MINE AREA PROVIDED BY P4 PRODUCTION DATED: DECEMBER 2007.
- US CENSUS BUREAU 2007 TIGER LINE DATA

DESIGNED BY	C DUFFY	02/24/11
DRAWN BY	C FOWLER	02/24/11
CHECKED BY	E MARKS	02/24/11
APPROVED BY	C FOULK	02/24/11
PROJECT MANAGER	V DRAIN	02/24/11
CLIENT APPROVAL	B KOCH	02/24/11
CLIENT REFERENCE NO.		

P4 Production, LLC

PROJECT LOCATION: BALLARD, HENRY AND ENOCH VALLEY MINES
PROJECT: RADIOLOGICAL BACKGROUND SAP
TITLE: GEOLOGIC MAP WITH MINE WASTE ROCK AND PIT BOUNDARIES

MWH

DRAWING 3-2
REVISION 1
FILE NAME 1005813D186-1

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The relative amounts of Wells Formation and Dinwoody Formation disturbed by the mining footprint is more difficult to estimate as only a fraction of the stratigraphic thickness of these thick units is either included in the mine pits or buried under the waste rock dumps. This assessment is qualitative based on the general configuration of the mines depicted on the geologic map (Figure 3-2 and the cross-section in Figure 2-2). What is noted is that where waste rock is placed on the Dinwoody Formation, the area covered is approximately equal to that of the Rex Chert/Cherty Shale, which is removed or covered by waste rock. Therefore, it is assumed that 250 feet of the Dinwoody Formation is affected by mining based on an average thickness similar to the Rex Chert/Cherty Shale, discussed above.

Only thin slices of the Wells Formation are excavated by the highwalls of the mine pits. This can be exaggerated in a plan view map due to the dip of the geologic units (illustrated on Figure 3-1). There are several locations at the Henry and Ballard Mines where waste rock is placed on the Wells Formation, but these areas are relatively small. Mine pit cross-sections suggest that an average stratigraphic thickness of 60 feet of Wells Formation is excavated in pit walls. However, because some waste rock dumping also occurs on the Wells Formation, it is assumed that 100 feet of stratigraphic thickness is impacted by mining.

Given the thicknesses of the individual formations and their members discussed above, a total of 765 feet of geologic strata are potentially affected in the "typical footprint" of the phosphate mines. Each disturbed unit represents the following ratio and calculated percentage of the total affected strata:

- Dinwoody Formation – 250/765 (feet) or 32.7%
- Rex Chert/Cherty Shale Member – 250/765 (feet) or 32.7%
- Meade Peak Member – 165/765 (feet) or 21.6%
- Wells Formation – 100/765 (feet) or 13.0%

P4 will use this relative distribution per geologic unit in the mined areas as a weighting scheme to calculate the representative background concentrations for the individual COPCs.

Note that the underlying assumption inherent in this analysis is that this mine–affected vertical distance through each of the geologic formations and the ratios that result are expressed at a pre-mine site as colluvial soils covering these same proportions.
The statistical limits (95% UCL and 95% USL) for each COPC in soil overlying each geologic unit will be multiplied by the respective weighting factor for that geologic unit. [Note: Because the four geologic units are each represented by 20 background samples, weighting factors are needed to adjust the statistical limits for each geological unit according to the actual "affected stratigraphic thickness" that it represents.] The sum of the weighted statistical limits for the four geologic units represents the background concentration for the COPC being evaluated. Mathematically this is expressed as:

$$\overline{X_{Dinwoody}}(0.327) + \overline{X_{Rex}}(0.327) + \overline{X_{MP\ Member}}(0.216) + \overline{X_{Wells}}(0.130) = \overline{X_{BK}}$$

where:

$\overline{X_n}$ = Respective COPC statistical limit (95% UCL and 95% USL) of 20 samples for each of the geologic units

$\overline{X_{BK}}$ = Overall weighted background concentration for the COPC

A detailed description of the statistical evaluation procedures to be performed on the background data was presented in the *Background Levels Development Technical Memorandum* (MWH, 2013b). Briefly, the background data will be statistically evaluated to identify and remove outliers, as appropriate. Then, the following un-pooled statistics for each COC in each of the four formations will be derived and presented:

- Box and whisker plots;
- Calculated UCLs on the mean; and
- Calculated 95% USLs.

Additionally, P4 will report the following statistics for the pooled data for each COC:

- Weighted values for the 95% UCLs on the mean as proposed in this SAP;
- Un-weighted (combined 80 sample) values for the 95% UCLs on the mean;
- Weighted values for the 95% USLs as proposed in this SAP; and
- Un-weighted (combined 80 sample) values for the 95% USLs.

Results of the updated statistical evaluation will be reviewed to ensure that the appropriate statistical measure is recommended. However, it should be noted that the 95% USL (USL95) was recommended for all of the media (soils, surface water, groundwater, etc.) in the *Background Levels Development Technical Memorandum* (MWH, 2013b) for detected analytes with sufficient sampling results to perform a statistical evaluation. The USL95 will also be recommended for the updated upland soils background levels, when appropriate. P4 in conjunction with the A/Ts will select the appropriate background value from the un-pooled or combined (80 sample) statistics.

4.0 DATA REPORTING

While this SAP is intended to help guide a specific investigation at the study locations, this investigation is supplemental to the overall P4 Site RI/FS. It is anticipated that the data collected as part of this investigation will be presented in a Data Summary Report (DSR) and utilized as part of the Ballard Mine FS process as well as in the individual RI Reports and risk assessments for Henry and Enoch Valley Mines. The raw data and data validation reports will be submitted to the A/T upon request when available. A data validation summary (DVS) consisting of validated data tables will be submitted to the A/Ts within approximately 120 days from the date of collection of the last sample from this field program.

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TABLES

TABLE 2-1 RADIOLOGICAL AND BACKGROUND AREA INVESTIGATION DATA QUALITY OBJECTIVES	
Step 1 - State the Problem	Phosphoria Formation waste rock has been placed in the various dumps and backfilled mine pits around the mines. Researchers have noted that concentrations of uranium and other metals/metalloids are enriched in the Meade Peak Member of the Phosphoria Formation. As a result, to compare the risks posed by the disturbed areas at the Sites, it is necessary to fully understand what the pre-mined or natural levels of uranium and other soil COPCs (i.e., primarily metals/metalloids) are in a similar background area. A Baseline l Risk Assessment (BRA) was performed as part of the draft Ballard Mine RI Report (MWH, 2013a) to evaluate the potential chemical impacts of detected COPCs in the various media on human health and the environment. P4 also evaluated radiogenic risks associated with uranium in the BRA based on total uranium concentrations in soil. Chemical and radiological risks exceeded EPA and IDEQ risk criteria for several pathways and receptors. Because of the conservative assumptions that are needed to address uncertainties in modeling radiological exposures and risks from total uranium concentrations in soil, it is probable that the human health risk estimates for the Ballard Site are a overestimation of incremental risk (above background). This issue also applies to other Site COPCs, primarily metals. The background samples collected during the RI are representative of only a portion of the potential area disturbed by the mining operations, and did not include soils derived from, and overlying, the Phosphoria Formation. Risk management plans must have a sound, defensible technical basis, and a full understanding of incremental chemical and radiogenic risks above background should enable risk managers to make informed decisions regarding risk management options. Risk management decisions for naturally occurring chemicals and radionuclides are based on limiting the excess risk above that which would have occurred in the absence of site-related impacts

TABLE 2-1 RADIOLOGICAL AND BACKGROUND AREA INVESTIGATION DATA QUALITY OBJECTIVES	
	(i.e., incremental risk above background). Unfortunately, there is insufficient radiological data for the Sites. In addition, no background data on the “pre mined” concentrations of uranium and several other COPCs in surface soils within the complete mined footprint exist to which current data collected from the reclaimed mine areas can be compared. It is unclear if a better understanding the background condition will significantly change future risk management decisions, but because there is appreciable risk and a high level of uncertainty in the risk calculations, further quantification of the background COPC and radiological conditions is warranted to help ensure incremental risk is appropriately characterized regardless of the outcome. As a result, direct measurement of uranium series radionuclides, both On-Site and at background locations and collection of COPC data from the Phosphoria Formation, will provide for a more realistic estimation of the radiogenic and chemical human and ecological risks. Planning team, decision makers, and principal data users include P4 and the A/T.
Step 2 – Identify the Goals of the Study	<u>Principal Study Question 1:</u> Are representative background data available to accurately evaluate incremental risk associated with uranium series radionuclides and other Site COPCs? Such data should be collected over an undisturbed area or areas that are representative of a typical phosphate mine footprint and include soils located over the major geologic units that are mined and processed and/or where external waste rock dumps are placed. Such a background area or areas should contain locations where undisturbed soil samples can be collected and is capable of containing a phosphate mine (i.e., is not a wetlands or other area where the mining land use would be restricted). <u>Alternative actions:</u>

TABLE 2-1 RADIOLOGICAL AND BACKGROUND AREA INVESTIGATION DATA QUALITY OBJECTIVES	
	1. No action. Existing soil background data cover the range of conditions needed for a representative background. 2. Background data are insufficient and do not cover the range of conditions represented of disturbed areas; therefore, additional background sampling is required. <u>Estimation statement:</u> To address if a sufficient number of samples have been collected in a background area that is representative of the Sites, the data should be representative of soils formed across the geology typically disturbed by phosphate mining at the Sites. A typical phosphate mine may involve various portions of four general unique geologic units: • Uppermost Wells Formation • Meade Peak Member of the Phosphoria Formation (the ore host) • Rex Chert and Cherty Shale Members of the Phosphoria Formation • Dinwoody Formation Randomly located samples are needed in soils overlying each of the geologic units indicated above in undisturbed areas for the radiogenic and non-radiogenic COPCs. If previous soil sampling has not been conducted across these geologic units, or the portions of these units typically disturbed by mine, then the background data are not representative. Furthermore, a sampling plan is needed to obtain representative data. <u>Principal Study Question 2:</u> Given that total uranium data are available for the Sites, are additional data needed to reduce the uncertainty in the risks posed to human health and the environment from uranium and associated radiogenic daughter products both

TABLE 2-1 RADIOLOGICAL AND BACKGROUND AREA INVESTIGATION DATA QUALITY OBJECTIVES	
	at the Sites and in a suitable Background Area(s)? Such data may include (for both On-Site and in a Background Area(s)): a GPS-based gamma survey, exposure rates measurements (using an HPIC), collection of total uranium and Ra-226 data by soil sampling, and radon flux measurements. Alternative actions: 1. No action, existing uranium data are sufficient. 2. Site soil data indicate impacts by uranium series radionuclides; however, the data are sufficient for realistically assessing risks and no additional sampling is warranted. 3. Site soil data indicate impacts by uranium series radionuclides potentially above a level of concern using conservative assumptions, and therefore, additional sampling is necessary to evaluation potential exposures. Estimation statement: As the existing data using standard USEPA calculations indicate an unacceptable risk from uranium and its decay products, are more realistic measures of exposure available to reduce the uncertainty in the risk assessment? Any such data to develop more realistic risk estimates needs to be attained in both On-Site and a representative Background Area(s) so that incremental risk estimations can be made.
Step 3 – Identify Information Inputs	The information inputs for the decision process includes the following items that may already exist or will need to be collected: • Existing operational history and background information for the Sites and the proposed Background Area(s) • Existing COPC data including total uranium data (Appendix A-2 of the *RI/FS Work Plan*). It is noted that samples have been collected from over the Wells Formation (10 samples) and Dinwoody Formation (20 samples) during the 2009 soil and vegetation sampling program. • Risk estimates developed in the BRA for the Ballard Mine (MWH, 2013a)

TABLE 2-1
RADIOLOGICAL AND BACKGROUND AREA INVESTIGATION
DATA QUALITY OBJECTIVES

	• List of soil COPCs and radiological measurements relevant to risk estimation for uranium series radionuclides • Existing and refined conceptual site models • Location and geologic maps • Risk-based screening benchmarks for COPCs
Step 4 – Define the Boundaries of the Study	Spatial boundaries: • Site waste rock areas as defined in the *RI/FS Work Plan.* • Background areas representative of a typical phosphate mine footprint which have not been developed as a mine (Figures 2-3 and 2-5). • Because the hypothetical length of a mine along strike is less critical (i.e., the geology general does not vary significantly), the width perpendicular to geologic strike is the focus of characterization. An arbitrary transect of 800 feet wide in the direction of strike by approximately 2,500 feet in the direction of geologic dip. Vertical boundary: Soil – Maximum depth of soil sampling will be no more than approximately 1 foot below ground surface (bgs). Temporal boundary: Radionuclide surveys and soil sample collection is planned for summer 2014. Practical constraints: Rock, or other substrate (i.e., physical) conditions preventing soil sampling to depth. Heavily vegetated areas may also not be conducive to sampling.
Step 5 – Develop the Analytic Approach	Principal Study Question 1: Identify a background area or areas where the full stratigraphic section, represented in a typical phosphate mine area, is present. Two such background areas (Caldwell Canyon area and the proposed P4 Blackfoot Bridge Mine) have been identified near P4's existing mine site. The radiologic measurements and soil sampling will be conducted within areas

TABLE 2-1 RADIOLOGICAL AND BACKGROUND AREA INVESTIGATION DATA QUALITY OBJECTIVES	
	representative of the typical footprint of a phosphate mine such as Henry or Enoch Valley Mines (approximately 1,000 to 2,000 feet wide [from top to bottom]). Establish a rectangular area approximately 2,500 feet in length and 800 feet wide. The rectangular area will be further divided into the four strata to be: (1) Wells Formation; (2) Meade Peak Member; (3) Rex Chert/Cherty Shale Member, and (4) Dinwoody Formation. Soils samples for non-radiological COPCs will not be necessary or collected from the Dinwoody Formation. GPS-based gamma surveys measurements will be collected continuously at 100 foot intervals along approximately 1,000 to 2,000 foot long traverse lines within the rectangular area (total of 10 traverse lines). 15 radon flux measurements will be collected randomly throughout each of the four geologic units (for a total of 60 from each Background Area). These data will be translated into outdoor and indoor radon concentrations, for use in the radiological risk assessment. Composite soil samples for total uranium and the other COPCs will be collected from random locations within each geologic unit not covered by previous sampling (i.e., Meade Peak and Rex Chert/Cherty Shale Members, and Wells Formation). Soil sampling at each location will be consistent with equipment and procedures previously used on the Sites using composite samples (MWH, 2009). Based on the survey and expression of the geologic units, select 10 locations (100 m^2 each) for correlation studies across the four units. GPS-based surveys will be performed at each of these locations along transects spaced at 5 feet intervals; direct (static) gamma and HPIC measurements will be made; and soil samples will be collected for analysis of total uranium and Ra-226 and other radionuclides (K-40 and Th-232). These data will be used to develop a correlation between gamma count and exposure rates, and gamma count

TABLE 2-1

RADIOLOGICAL AND BACKGROUND AREA INVESTIGATION

DATA QUALITY OBJECTIVES

	rates and Ra-226 concentrations in soil, for use in the risk assessment and estimation of dose. Principal Study Question 2: Collect radiological information at the Sites where direct comparisons of radiological data and evaluations through risk calculations can be made to the representative background location. Radiological data will be collected throughout the waste rock dumps and backfilled areas of the Ballard, Henry, and Enoch Valley mines. GPS-based gamma surveys will be performed along parallel transects spaced at 200-foot intervals in these disturbed areas. Select a total of three major survey areas (or units) for correlation studies throughout the mines likely representing the range of gamma-counts (low, medium, and high), which likely represent different mine reclamation conditions and estimation of dose. Radon flux measurements will be made at 15 randomly selected locations in each major survey area (for a total of 45). These data will be translated into outdoor and indoor radon concentrations, for use in the radiological risk assessment. Based on the GPS-gamma survey, select a minimum of 10 locations (100 m^2 each) for correlation studies across the three survey units. Gamma-based surveys will be performed along transects spaced at 5 feet intervals; direct (static) gamma and HPIC measurements will be made; soil samples will be collected for analysis of uranium, Ra-226, and other radionuclides (K-40 and Th-232). These data will be used to develop a correlation between gamma count and exposure rates, and gamma count rates and Ra-226 concentrations in soil, for use in the risk assessment. Soil samples for COPC analytes will not be necessary On-Site because data are available through previous study.

TABLE 2-1 RADIOLOGICAL AND BACKGROUND AREA INVESTIGATION DATA QUALITY OBJECTIVES	
Step 6 – Specify Performance or Acceptance Criteria	The precision, accuracy, representativeness, comparability, and completeness criteria and the minimum detection limits will be used to evaluate the usability of analytical data in making decisions about the nature and extent of COPCs and uranium daughter products in soil and be acceptable for risk calculations. Data will be collected from Background and On-Site areas. All data must meet approved usability as defined in the RI/FS QAPP and QAPP Addendum in addition to data requirements specified in the Appendices A and B – the FSP and QAPP. Specific details of the sampling design are set forth in the plan presented herein using the considerations that have been documented.
Step 7 – Develop the Plan for Obtaining Data	The sampling rationale and design are based on knowledge of the selected representative Background Area(s) and on knowledge of historical site operations and data that have been collected as presented in Section 2.0 of this SAP. The sampling design will be further evaluated if new data suggests that the proposed locations and analytes are not sufficient to characterize the risks associated with uranium, uranium daughter products and COPCs in soils in the Background Area(s) and On-Site. The field and quality assurance requirements and methods/procedures are presented in the FSP (Appendix A) and QAPP (Appendix B).

Table 3-1
Sample Collection Summary

Location	Sample Investigation	# of Primary Samples	Analyte List and Method[1]
Blackfoot Bridge Background Area	GPS Gamma Survey	Continuous 100 ft transects	Gamma Count Rate
	Radon Flux Measurements	Dinwoody Fm – 15 Rex Chert – 15 Meade Peak – 15 Wells Fm - 15	Rn-222 by Method 115
	Upland Soil	Dinwoody Fm – 5 Rex Chert – 10 Meade Peak – 10 Wells Fm - 5	Site COPCs[2] by 6020A/7471A Ra-226, K-40, Th-232 by 901.1M
Caldwell Canyon Bridge Background Area	GPS Gamma Survey	Continuous 100 ft transects	Gamma Count Rate
	Radon Flux Measurements	Dinwoody Fm – 15 Rex Chert – 15 Meade Peak – 15 Wells Fm - 15	Rn-222 by Method 115
	Upland Soil	Dinwoody Fm – 5 Rex Chert – 10 Meade Peak – 10 Wells Fm - 5	Site COPCs[2] by 6020A/7471A Ra-226, K-40, Th-232 by 901.1M
On-Site Areas Ballard, Henry, and Enoch Valley Mine Sites	GPS Gamma Survey	Continuous 200 ft transects	Gamma Count Rate
	Radon Flux Measurements	Low gamma survey area – 15 Medium gamma survey area – 15 High gamma survey area - 15	Rn-222 by Method 115
Correlation Study Locations[3]	GPS Gamma Survey	Continuous 5 ft transects Blackfoot Bridge 5 Caldwell Canyon – 5 On-Site -10	Gamma Count Rate
	Static Gamma Measurements	Blackfoot Bridge 5 Caldwell Canyon – 5 On-Site -10	Gamma Count Rate
	HPIC Measurements	Blackfoot Bridge 5 Caldwell Canyon – 5 On-Site -10	Gamma Exposure Rate
	Radon Flux Measurements	Blackfoot Bridge 5 Caldwell Canyon – 5 On-Site -10	Rn-222 by Method 115
	Upland Soil	Blackfoot Bridge 5 Caldwell Canyon – 5 On-Site -10	U, total by 6020A Ra-226, K-40, Th-232 by 901.1M

Notes:
HPIC – high pressure ionization chamber
COPC – constituents of potential concern
[1] Analytical methods, reporting limits, method detection limits, and screening criteria are presented in the QAPP Table 1-2
[2] 6020A ICPMS metals are Sb, As, B, Cd, Cr, Co, Cu, Mn, Mo, Ni, Se, Ag, Tl, U, V, and Zn.
[3] The correlation sample locations will be based on the field GPS-based gamma survey results.